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[Title of the Invention]

ADJUSTING DEVICE FOR SHAKE CORRECTION CAMERA, SHAKE CORRECTION CAMERA AND METHOD OF ADJUSTING SHAKE CORRECTION CAMERA

[Abstract]

[Object]

Displacement in the detection direction of angular velocity detecting unit is adjusted in the final assembly state of the camera.

[Constitution]

An adjusting device for a shake correction camera is a device for adjusting a shake correction function of the shake correction camera and includes: an information transferring unit for transferring information to and from the shake correction camera; a shake applying unit for applying a sinusoidal vibration with a predetermined angular velocity amplitude in the first and the second direction of the shake correction camera; a first calculating unit for calculating a

first and a second angle displacement amount between the first and the second direction and the directions in which the first and the second angular velocity detecting unit detect the angular velocity based on the output values of the first and second angular velocity detecting units of the shake correction camera produced when the sinusoidal vibration is applied in the first and the second direction of the shake correction camera; a second calculating unit for calculating a first and a second angle displacement adjustment value based on the first and the second angle displacement amount; and a writing unit for writing the first and the second angle displacement adjustment value in the storing unit of the shake correction camera.

[Claims for the Patent]

[Claim 1]

An adjusting device for adjusting the shake correction function of a shake correction camera including:

an optical axis varying unit for varying the optical axis of a photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration;

a first angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the first direction;

a second angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the second direction;

a storing unit for storing a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which said first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which said second angular velocity detecting unit detects the angular

velocity;

a first angle displacement correcting unit for correcting an error due to the first angle displacement amount of output of said first angular velocity detecting unit by said first angle displacement adjustment value stored in said storing unit and the output of said second angular velocity detecting unit; and

a second angle displacement correcting unit for correcting an error due to the second angle displacement amount of output of said second angular velocity detecting unit by the second angle displacement adjustment value stored in said storing unit and the output of said first angular velocity detecting unit; the adjusting device characterized by comprising:

an information transferring unit for transferring information to and from the shake correction camera;

a shake applying unit for applying a sinusoidal vibration with a predetermined angular velocity amplitude in the first and the second direction of the shake correction camera;

a first calculating unit for calculating a first angle displacement amount between the first direction and the direction in which said first angular velocity detecting unit detects the angular velocity and a second angle displacement amount between the second

direction and the direction in which said second angular velocity detecting unit detects the angular velocity based on the output values of said first and second angular velocity detecting units produced when the sinusoidal vibration is applied to the shake correction camera;

a second calculating unit for calculating a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which said first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which said second angular velocity detecting unit detects the angular velocity based on the first and the second angle displacement amount calculated by said first calculating unit; and

a writing unit for writing the first and the second angle displacement adjustment value calculated by said second calculating unit in said storing unit of the shake correction camera.

[Claim 2]

The adjusting device for a shake correction camera according to claim 1, characterized in that

said first calculating unit calculates the first and the second angle displacement amount based on the

maximum and the minimum value of each of the output values of said first and second angular velocity detecting units.

[Claim 3]

An adjusting device for adjusting the shake correction function of a shake correction camera including:

an optical axis varying unit for varying the optical axis of a photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration;

a first angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the first direction;

a second angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the second direction;

a storing unit for storing a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which said first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second

direction and the direction in which said second angular velocity detecting unit detects the angular velocity;

a first angle displacement correcting unit for correcting an error due to the first angle displacement amount of output of said first angular velocity detecting unit by the first angle displacement adjustment value stored in said storing unit and the output of said second angular velocity detecting unit; and

a second angle displacement correcting unit for correcting an error due to the second angle displacement amount of output of said second angular velocity detecting unit by the second angle displacement adjustment value stored in said storing unit and the output of said first angular velocity detecting unit; the adjusting device characterized by comprising:

an information transferring unit for transferring information to and from the shake correction camera;

a shake applying unit for applying a sinusoidal vibration with a predetermined angular amplitude in the first and the second direction of the shake correction camera;

a first calculating unit for calculating a first angle displacement amount between the first direction and the direction in which said first angular velocity

detecting unit detects the angular velocity and a second angle displacement amount between the second direction and the direction in which said second angular velocity detecting unit detects the angular velocity based on a first and a second calculated value in which a first output value of said first angular velocity detecting unit and a second output value of said second angular velocity detecting unit produced when the sinusoidal vibration is applied in the first direction of the shake correction camera are integrated or accumulated and a third and a fourth calculated value in which a third output value of said first angular velocity detecting unit and a fourth output value of said second angular velocity detecting unit produced when the sinusoidal vibration is applied in the second direction are integrated or accumulated;

a second calculating unit for calculating a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which said first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which said second angular velocity detecting unit detects the angular velocity based on the first and the second angle displacement amount calculated by said first

calculating unit respectively; and

a writing unit for writing the first and the second angle displacement adjustment value calculated by said second calculating unit in said storing unit of the shake correction camera.

[Claim 4]

The adjusting device for a shake correction camera according to claim 3, characterized in that

said first calculating unit calculates the first and the second angle displacement amount based on the maximum and the minimum value of each of the first, the second, the third and the fourth calculated value.

[Claim 5]

A shake correction camera including:

an optical axis varying unit for varying the optical axis of a photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration;

a first angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the first direction;

a second angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the second direction;

a storing unit for storing a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which said first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which said second angular velocity detecting unit detects the angular velocity;

a first angle displacement correcting unit for correcting an error due to the first angle displacement amount of output of said first angular velocity detecting unit by the first angle displacement adjustment value stored in said storing unit and the output of said second angular velocity detecting unit; and

a second angle displacement correcting unit for correcting an error due to the second angle displacement amount of output of said second angular velocity detecting unit by the second angle displacement adjustment value stored in said storing unit and the output of said first angular velocity detecting unit; the shake correction camera characterized in that a first angle displacement amount between the first direction and the direction in which said first angular velocity detecting unit detects the

angular velocity and a second angle displacement amount between the second direction and the direction in which said second angular velocity detecting unit detects the angular velocity are calculated based on a first output value of said first angular velocity detecting unit and a second output value of said second angular velocity detecting unit produced when a first sinusoidal vibration with a predetermined angular velocity amplitude is applied in the first direction of the shake correction camera and a third output value of said first angular velocity detecting unit and a fourth output value of said second angular velocity detecting unit produced when a second sinusoidal vibration with a predetermined angular velocity amplitude is applied in the second direction of the shake correction camera and the first and the second angle displacement adjustment value are calculated based on the first and the second angle displacement amount respectively.

[Claim 6]

The shake correction camera according to claim 5, characterized in that

the first and the second angle displacement amount are calculated based on the maximum and the minimum value of each of the first, the second, the third and the fourth output value.

[Claim 7]

A shake correction camera including:

an optical axis varying unit for varying the optical axis of a photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration;

a first angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the first direction;

a second angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the second direction;

a storing unit for storing a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which said first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which said second angular velocity detecting unit detects the angular velocity;

a first angle displacement correcting unit for correcting an error due to the first angle displacement amount of output of said first angular velocity detecting unit by the first angle displacement

adjustment value stored in said storing unit and the output of said second angular velocity detecting unit; and

a second angle displacement correcting unit for correcting an error due to the second angle displacement amount of output of said second angular velocity detecting unit by the second angle displacement adjustment value stored in said storing unit and the output of said first angular velocity detecting unit; the shake correction camera characterized in that a first angle displacement amount between the first direction and the direction in which said first angular velocity detecting unit detects the angular velocity and a second angle displacement amount between the second direction and the direction in which said second angular velocity detecting unit detects the angular velocity are calculated based on a first and a second calculated value in which a first output value of said first angular velocity detecting unit and a second output value of said second angular velocity detecting unit produced when a first sinusoidal vibration with a predetermined angular amplitude is applied in the first direction of the shake correction camera are integrated or accumulated and a third and a fourth calculated value in which a third output value of said first angular velocity detecting unit and a fourth output value of said second angular velocity

detecting unit produced when a second sinusoidal vibration with a predetermined angular amplitude is applied in the second direction of the shake correction camera are integrated or accumulated and the first and the second angle displacement adjustment value are calculated based on the first and the second angle displacement amount calculated by said first calculation unit.

[Claim 8]

The shake correction camera according to claim 7, characterized in that

the first and the second angle displacement amount are calculated based on the maximum and the minimum value of each of the first, the second, the third and the fourth calculated value.

[Claim 9]

A method of adjusting the shake correction function of a shake correction camera including:

an optical axis varying unit for varying the optical axis of a photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration; and

a first and a second shake detecting unit for detecting an angular velocity caused by a shake in the directions substantially coinciding with the first and the second direction respectively; the method

characterized by comprising the steps of:

applying a sinusoidal vibration with a predetermined angular velocity amplitude in the first and the second direction of the shake correction camera;

calculating a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which said first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which said second angular velocity detecting unit detects the angular velocity based on the output values of said first and second angular velocity detecting units of the shake correction camera or the maximum and the minimum value thereof at that point; and

correcting an error due to the first angle displacement amount of output of said first angular velocity detecting unit by the first angle displacement adjustment value and the output of said second angular velocity detecting unit and an error due to the second angle displacement amount of output of said second angular velocity detecting unit by the second angle displacement adjustment value and the output of said first angular velocity detecting unit.

[Claim 10]

A method of adjusting the shake correction function of a shake correction camera including:

an optical axis varying unit for varying the optical axis of a photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration; and

a first and a second shake detecting unit for detecting an angular velocity caused by a shake in the directions substantially coinciding with the first and the second direction respectively; the method characterized by comprising the steps of:

applying a sinusoidal vibration with a predetermined angular amplitude in the first and the second direction of the shake correction camera;

calculating a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which said first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which said second angular velocity detecting unit detects the angular velocity based on the integrated or the accumulated values of the output values of said first and second angular velocity detecting units of the shake correction camera or the maximum and the minimum value

thereof at that point; and

correcting an error due to the first angle displacement amount of output of said first angular velocity detecting unit by the first angle displacement adjustment value and the output of said second angular velocity detecting unit and an error due to the second angle displacement amount of output of said second angular velocity detecting unit by the second angle displacement adjustment value and the output of said first angular velocity detecting unit.

[Detailed Description of the Invention]

[0001]

[Industrial Application Field]

The present invention relates to an adjusting device for a shake correction camera capable of correcting image shake due to hand shake produced at the time of taking a picture, the shake correction camera and a method of adjusting the shake correction camera.

[0002]

[Conventional Art]

As a conventional shake correction camera of this type, there has been known the following shake correction camera. An angular velocity detecting circuit using an angular velocity senor detects an angular velocity due to shake in two directions on a

vertical plane at least perpendicular to the optical axis of a camera. The optical axis of a photographing optical system is moved by shifting a shake correcting lens (or, a vibration-proof lens) being part of a photographing lens in substantially the same direction as the detection direction according to the detected angular velocity. The photographing optical system is driven in such a manner that the rotation of an actuator such as a motor is reduced by a gear and the rotational motion is converted to a linear motion. Thereby, image shake due to shake generated in a camera is corrected (this control is referred to also as vibration-proof control).

[0003]

Such a camera is separated into some portions (sub-assembly parts) in a production stage and produced. The operation of each sub-assembly part is inspected and then a final assembly is performed. For example, a correction lens shifting mechanism for shifting a correction lens by rotating a motor is inspected as to whether it is normally operated as one assembly part and then it is assembled into a camera body. The angular velocity detecting circuit for detecting an angular velocity due to hand shake is similar to the above.

[0004]

[Problems to be Solved by the Invention]

The above conventional shake correction camera has the following problems. Firstly, even if a correction lens shifting mechanism or an angular velocity detecting circuit are non-defective at the time of inspecting its operation at a sub-assembly parts stage, the operation can be defective at a stage where they are assembled into a camera body or good operative performances cannot be obtained. In the final assembly state of the camera, the correction lens shifting mechanism and/or the angular velocity detecting circuit cannot be inspected.

[0005]

Secondly, the output of an angular velocity sensor used in an angular velocity detecting circuit has an individual difference (dispersion between apparatus). The output value of each angular velocity sensor is not constant when a predetermined angular velocity is applied to the angular velocity sensors. An amplifier for an angular velocity detecting circuit disperses in amplification factor. In most cases, the output value of the angular velocity detecting circuit is converted to a digital value by an A/D converter incorporated in a microcomputer. The A/D converter has also an individual difference and a digital value A/D converted from a predetermined input voltage is not constant. It is not so much difficult to adjust dispersion in the gain of the angular velocity detecting circuit in a

sub-assembly state, however, there is still left an error caused by dispersion in the A/D converter. In the case where shake is corrected with such a gain dispersed, a problem is caused in that a shake correction is not accurately performed.

[0006]

Thirdly, the angular velocity sensor used in the angular velocity detecting circuit is supported in space by an oscillator-wire shaped supporting member for determining the direction of an axis detecting the angular velocity of rotational motion, as disclosed in, for example, Japanese Patent Laid-Open No. 2-228518. In the case where the angular velocity sensor in which the legs of the supporting member are fixed, it is prone to cause an individual difference of a detecting axis in terms of structure. Furthermore, there is produced an error in the attachment direction at a stage where the angular velocity sensor is attached to the angular velocity detecting circuit and the angular velocity detecting circuit is incorporated into the camera body. Those cause displacement between the direction in which the angular velocity detecting circuit detects an angular velocity and the direction the shake correction lens is actually shifted to move the optical axis (the displacement is also referred to as detection angle displacement, because the displacement is dominant in the direction detected by

the angular velocity detecting circuit). The detection angle displacement can be 5° or more. Thus, there is a problem in that the detection angle displacement between the angular velocity detecting direction and the optical axis moving direction cannot accurately perform a shake correction.

[0007]

The present invention has been made to solve the above problems and for its object to perform an accurate shake correction by inspecting the operation of each sub-assembly part for the shake correction lens shifting mechanism and the angular velocity detecting circuit and adjusting the dispersion in the gain of the output value between apparatus of each sub-assembly part.

[0008]

[Means for Solving the Problems]

To achieve the above object, according to a first solution aspect of the present invention, in an adjusting device for adjusting the shake correction function of a shake correction camera including: an optical axis varying unit for varying the optical axis of a photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration; a first angular velocity detecting unit for detecting an angular velocity caused by a shake in

the direction substantially coinciding with the first direction; a second angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the second direction; a storing unit for storing a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity; a first angle displacement correcting unit for correcting an error due to the first angle displacement amount of output of the first angular velocity detecting unit by the first angle displacement adjustment value stored in the storing unit and the output of the second angular velocity detecting unit; and a second angle displacement correcting unit for correcting an error due to the second angle displacement amount of output of the second angular velocity detecting unit by the second angle displacement adjustment value stored in the storing unit and the output of the first angular velocity detecting unit; the adjusting device is characterized by including: an information transferring unit for transferring information to and from the shake

correction camera; a shake applying unit for applying a sinusoidal vibration with a predetermined angular velocity amplitude in the first and the second direction of the shake correction camera; a first calculating unit for calculating a first angle displacement amount between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle displacement amount between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity based on the output values of the first and second angular velocity detecting units produced when the sinusoidal vibration is applied to the shake correction camera; and a second calculating unit for calculating a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity based on the first and the second angle displacement amount calculated by the first calculating unit; and a writing unit for writing the first and the second angle displacement adjustment value calculated by the second

calculating unit in the storing unit of the shake correction camera.

[0009]

A second solution aspect according to the first solution aspect of the present invention is characterized in that the first calculating unit calculates the first and the second angle displacement amount based on the maximum and the minimum value of each of the output values of the first and second angular velocity detecting units.

[0010]

According to a third solution aspect of the present invention, in an adjusting device for adjusting the shake correction function of a shake correction camera including: an optical axis varying unit for varying the optical axis of a photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration; a first angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the first direction; a second angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the second direction; a storing unit for storing a first angle displacement adjustment value for adjusting an angle displacement

between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity; a first angle displacement correcting unit for correcting an error due to the first angle displacement amount of output of the first angular velocity detecting unit by the first angle displacement adjustment value stored in the storing unit and the output of the second angular velocity detecting unit; and a second angle displacement correcting unit for correcting an error due to the second angle displacement amount of output of the second angular velocity detecting unit by the second angle displacement adjustment value stored in the storing unit and the output of the first angular velocity detecting unit; the adjusting device is characterized by including: an information transferring unit for transferring information to and from the shake correction camera; a shake applying unit for applying a sinusoidal vibration with a predetermined angular amplitude in the first and the second direction of the shake correction camera; a first calculating unit for calculating a first angle displacement amount between the first direction and the direction in which the

first angular velocity detecting unit detects the angular velocity and a second angle displacement amount between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity based on a first and a second calculated value in which a first output value of the first angular velocity detecting unit and a second output value of the second angular velocity detecting unit produced when the sinusoidal vibration is applied in the first direction of the shake correction camera are integrated or accumulated and a third and a fourth calculated value in which a third output value of the first angular velocity detecting unit and a fourth output value of the second angular velocity detecting unit produced when the sinusoidal vibration is applied in the second direction are integrated or accumulated; a second calculating unit for calculating a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity based on the first and the second angle displacement amount calculated by the first calculating unit respectively;

and a writing unit for writing the first and the second angle displacement adjustment value calculated by the second calculating unit in the storing unit of the shake correction camera.

[0011]

A fourth solution aspect according to the third solution aspect of the present invention is characterized in that the first calculating unit calculates the first and the second angle displacement amount based on the maximum and the minimum value of each of the first, the second, the third and the fourth calculated value.

[0012]

According to a first solution aspect of a shake correction camera of the present invention, in the shake correction camera including: an optical axis varying unit for varying the optical axis of a photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration; a first angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the first direction; a second angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the second direction; a storing unit for storing a first angle

displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity; a first angle displacement correcting unit for correcting an error due to the first angle displacement amount of output of the first angular velocity detecting unit by the first angle displacement adjustment value stored in the storing unit and the output of the second angular velocity detecting unit; and a second angle displacement correcting unit for correcting an error due to the second angle displacement amount of output of the second angular velocity detecting unit by the second angle displacement adjustment value stored in the storing unit and the output of the first angular velocity detecting unit; the shake correction camera is characterized in that a first angle displacement amount between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle displacement amount between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity are calculated based on a first output

value of the first angular velocity detecting unit and a second output value of the second angular velocity detecting unit produced when a first sinusoidal vibration with a predetermined angular velocity amplitude is applied in the first direction of the shake correction camera and a third output value of the first angular velocity detecting unit and a fourth output value of the second angular velocity detecting unit produced when a second sinusoidal vibration with a predetermined angular velocity amplitude is applied in the second direction of the shake correction camera and the first and the second angle displacement adjustment value are calculated based on the first and the second angle displacement amount respectively.

[0013]

A second solution aspect according to the first solution aspect of the shake correction camera of the present invention is characterized in that the first and the second angle displacement amount are calculated based on the maximum and the minimum value of each of the first, the second, the third and the fourth output value.

[0014]

According to a third solution aspect of a shake correction camera of the present invention, in the shake correction camera including: an optical axis varying unit for varying the optical axis of a

photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration; a first angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the first direction; a second angular velocity detecting unit for detecting an angular velocity caused by a shake in the direction substantially coinciding with the second direction; a storing unit for storing a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity; a first angle displacement correcting unit for correcting an error due to the first angle displacement amount of output of the first angular velocity detecting unit by the first angle displacement adjustment value stored in the storing unit and the output of the second angular velocity detecting unit; and a second angle displacement correcting unit for correcting an error due to the second angle displacement amount of output of the second angular velocity detecting unit by the

second angle displacement adjustment value stored in the storing unit and the output of the first angular velocity detecting unit; the shake correction camera is characterized in that a first angle displacement amount between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle displacement amount between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity are calculated based on a first and a second calculated value in which a first output value of the first angular velocity detecting unit and a second output value of the second angular velocity detecting unit produced when a first sinusoidal vibration with a predetermined angular amplitude is applied in the first direction of the shake correction camera are integrated or accumulated and a third and a fourth calculated value in which a third output value of the first angular velocity detecting unit and a fourth output value of the second angular velocity detecting unit produced when a second sinusoidal vibration with a predetermined angular amplitude is applied in the second direction of the shake correction camera are integrated or accumulated and the first and the second angle displacement adjustment value are calculated based on the first and the second angle displacement amount calculated by the first calculation

unit.

[0015]

A fourth solution aspect according to the third solution aspect of the shake correction camera of the present invention is characterized in that the first and the second angle displacement amount are calculated based on the maximum and the minimum value of each of the first, the second, the third and the fourth calculated value.

[0016]

According to a first solution aspect of a method of adjusting the shake correction function of a shake correction camera of the present invention, in a method of adjusting the shake correction function of the shake correction camera including: an optical axis varying unit for varying the optical axis of a photographic optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration; and a first and a second shake detecting unit for detecting an angular velocity caused by a shake in the directions substantially coinciding with the first and the second direction respectively; the method is characterized by including the steps of: applying a sinusoidal vibration with a predetermined angular velocity amplitude in the first and the second direction of the shake correction camera; calculating a

first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity based on the output values of the first and second angular velocity detecting units of the shake correction camera or the maximum and the minimum value thereof at that point; and correcting an error due to the first angle displacement amount of output of the first angular velocity detecting unit by the first angle displacement adjustment value and the output of the second angular velocity detecting unit and an error due to the second angle displacement amount of output of the second angular velocity detecting unit by the second angle displacement adjustment value and the output of the first angular velocity detecting unit.

[0017]

According to a second solution aspect of a method of adjusting the shake correction function of a shake correction camera of the present invention, in a method of adjusting the shake correction function of the shake correction camera including: an optical axis varying unit for varying the optical axis of a photographic

optical system in a first and a second direction substantially perpendicular to the direction of the optical axis to correct a shake caused by vibration; and a first and a second shake detecting unit for detecting an angular velocity caused by a shake in the directions substantially coinciding with the first and the second direction respectively; the method is characterized by including the steps of: applying a sinusoidal vibration with a predetermined angular amplitude in the first and the second direction of the shake correction camera; calculating a first angle displacement adjustment value for adjusting an angle displacement between the first direction and the direction in which the first angular velocity detecting unit detects the angular velocity and a second angle displacement adjustment value for adjusting an angle displacement between the second direction and the direction in which the second angular velocity detecting unit detects the angular velocity based on the integrated or the accumulated values of the output values of the first and second angular velocity detecting units of the shake correction camera or the maximum and the minimum value thereof at that point; and correcting an error due to the first angle displacement amount of output of the first angular velocity detecting unit by the first angle displacement adjustment value and the output of the second angular

velocity detecting unit and an error due to the second angle displacement amount of output of the second angular velocity detecting unit by the second angle displacement adjustment value and the output of the first angular velocity detecting unit.

[0018]

[Operation]

According to the solution aspect of the present invention, a sinusoidal oscillation is applied to a first and a second direction being the direction in which the optical axis of a photographing optical system of the shake correction camera is varied and the first and the second amount of angle displacement is calculated between the first and the second direction and the angular velocity detecting direction by the first and the second angular velocity detecting unit based on the output values of the first and the second angular velocity detecting unit. In addition, the first and the second angle displacement adjustment value are calculated from the first and the second amount of angle displacement and stored in a storing unit. The output error of the first and the second angular velocity detecting unit is corrected based on the first and the second angle displacement adjustment value stored in the storing unit. Accordingly, an attachment error of the first and the second angular velocity detecting unit produced at the time of

assembling the camera does not influence the accuracy of shake correction.

[0019]

[Embodiments]

One embodiment of the present invention is described below with reference to the drawings. Figure 1 is a schematic diagram illustrating the configuration of portions of a camera, a communication tool and a shaking table. First, the portion on a camera side is described. The camera of the present embodiment is formed of photographic optical systems 11 to 14, a CPU 1, X and Y axis lens position detecting circuits 6 and 7 electrically connected to the CPU 1, X and Y axis motor driving circuits 2 and 3 and yaw and pitch angular velocity detecting circuits 8 and 9. The photographic optical systems 11 to 14 include four photographic lenses 11, 12, 13 and 14. The photographic lens 13 functions as a lens correcting image shake due to hand shake (hereinafter, referred to as a "vibration-proof lens 13"). The yaw and the pitch angular velocity detecting circuit 8 and 9 detect angular velocity due to hand shake in the yaw and the pitch direction in two axes (X and Y axes) direction on a plane surface orthogonal to a photographing optical axis. The CPU 1 is a one-chip microcomputer for controlling the sequence of the camera and has the calculation function of performing various calculations,

the clock timer function of measuring time, the timer interruption process of performing the process at a constant time interval, the PWM output function of outputting any duty, the function of A/D converting the output of the yaw and the pitch angular velocity detecting circuit 8 and 9, the communication function with the communication-tool side and the shutter function of performing an exposure process. The X and the Y axis motor driving circuit 2 and 3 drive the X and the Y axis motor 4 and 5 respectively to move the vibration-proof lens 13 in the X and the Y axis direction. The X and the Y axis lens position detecting circuit 6 and 7 detect positions in the X and the Y axis direction of the vibration-proof lens 13.

[0020]

The CPU 1 is electrically connected to an E2PROM 10, a half-depression SW 16, and a full-depression SW 17. The E2PROM 10 is a non-volatile memory and stores a gain adjustment value for correcting dispersion in the gain of the yaw and the pitch angular velocity detecting circuit 8 and 9 and a detection-angle displacement adjustment value for correcting detection direction displacement of angular velocity of the yaw and the pitch angular velocity detecting circuit 8 and 9. The half-depression SW 16 is a switch which is turned on by half depressing a release button and the full-depression SW 17 is a switch which is turned on by

fully depressing the release button.

[0021]

The operation of the camera is described below. The yaw and the pitch angular velocity detecting circuit 8 and 9 detect an angular velocity caused by a hand shake of the camera. The output values of the circuits are transmitted to the CPU 1. The CPU 1 A/D converts the output values to digital signals and detects the angular velocity of the hand shake. The CPU 1 performs a predetermined calculation based on the angular velocity, the gain adjustment value and the detection-angle displacement adjustment value stored in the E2PROM 10 to calculate an appropriate driving amount of the vibration-proof lens 13. The CPU 1 causes the X and the Y axis motor driving circuit 2 and 3 to drive the X and the Y axis motor 4 and 5 respectively. The rotary driving force of the X and the Y axis motor 4 and 5 is converted to a linear motion by, for example, a gear train to move the vibration-proof lens 13 at an appropriate velocity in the X and the Y axis direction so that a hand shake on the image surface is cancelled. The move of the vibration-proof lens 13 causes the CPU 1 to read the positions of the vibration-proof lens 13 in the X and the Y direction through the X and the Y axis lens position detecting circuit 6 and 7. In the following description, a mechanism for shifting the vibration-

proof lens 13 by the rotation of the X and the Y axis motor 4 and 5 is referred to as "vibration-proof lens shifting mechanism."

[0022]

On the communication tool side, there is provided a communication tool 15 electrically connected to the CPU 1 of the camera. The communication tool 15 transmits information to and receives it from the CPI 1 to perform various adjustments of the camera in synchronization with the operation of the camera. On the shaking table side, there is provided a shaking table 18 electrically connected to the communication tool 15. The shaking table 18 serves to shake the camera and shakes in a substantially sinusoidal wave shape in the X and the Y axis direction being the shift direction of the vibration-proof lens 13 in accordance with instructions from the communication tool 15 with the camera attached thereto.

[0023]

The adjustment of dispersion in gain and displacement in the detection angle of the angular velocity in the angular velocity detection is described below.

(1) Method of adjusting gain and correcting angle displacement

The yaw and the pitch angular velocity detecting circuit 8 and 9 are formed of angular velocity sensors

and amplifier circuits for amplify the signals thereof. Factors of dispersion in gain include dispersion in the outputs of the angular velocity sensors and the amplification factors of the amplifier circuits. Furthermore, in the camera in which the CPU 1 performs the A/D conversion like the present embodiment, the factors also include dispersion in the A/D converters in an individual CPU 1 or the reference voltage used in the A/D conversion. Figure 2 is a schematic diagram illustrating dispersion in the gains of the yaw and the pitch angular velocity detecting circuit 8 and 9. Factors of dispersion in the gains in the yaw and the pitch direction are simply taken as G1 and G2 respectively.

[0024]

The detection directions of the angular velocities of the yaw and the pitch angular velocity detecting circuit 8 and 9 do not accurately coincide with the move direction of the vibration-proof lens 13 based on the outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9, so that an error caused by an angle displacement is produced therebetween. Figure 3 is a chart describing the angle displacement. In Figure 3, the abscissa and the ordinate indicate the X and the Y axis drive direction of the vibration-proof lens 13 respectively. The X axis drive direction is displaced by an angle α with respect to the detection

direction of angular velocity by the yaw angular velocity detecting circuit 8. On the other hand, the Y axis drive direction is displaced by an angle β with respect to the detection direction of angular velocity by the pitch angular velocity detecting circuit 9. In this case, if a vector ω (the magnitude is ω and an angular velocity tilted counterclockwise by θ from the X axis drive axis direction) is given by hand shake, the outputs "u" and "v" of the yaw and the pitch angular velocity detecting circuit 8 and 9 are calculated by the following equations (Expression 1) and (Expression 2):

(Expression 1) $u = G1 \times \omega \times \cos(\theta + \alpha)$

(Expression 2) $v = G2 \times \omega \times \sin(\theta - \beta)$,

where, in Figure 3, gain dispersions G1 and G2 are taken as one respectively ($G1 = G2 = 1$) for better understanding.

[0025]

The outputs u1 and v1 of the yaw and the pitch angular velocity detecting circuit 8 and 9 in the case where the angular velocity applied to the camera is $\omega 1$ in magnitude and the X axis direction (i.e., $\theta = 0$) in the direction thereof are calculated by the following equations (Expression 3) and (Expression 4):

(Expression 3) $u1 = G1 \times \omega 1 \times \cos(\alpha)$

(Expression 4) $v1 = - G2 \times \omega 1 \times \sin(\beta)$.

[0026]

The outputs u2 and v2 of the yaw and the pitch angular velocity detecting circuit 8 and 9 in the case where the angular velocity applied to the camera is $\omega 2$ in magnitude and the Y axis direction (i.e., $\theta = 90°$) in the direction thereof are calculated by the following equations (Expression 5) and (Expression 6):

(Expression 5) $u2 = - G1 \times \omega 2 \times \sin(\alpha)$

(Expression 6) $v2 = G2 \times \omega 2 \times \cos(\beta)$.

[0027]

The gain dispersions G1 and G2 of the yaw and the pitch angular velocity detecting circuit 8 and 9 are calculated by the following equations (Expression 7) and (Expression 8) derived from the equations (Expression 3) and (Expression 6):

(Expression 7) $G1 = u1/(\omega 1 \times \cos(\alpha))$

(Expression 8) $G2 = u2/(\omega 2 \times \cos(\beta))$,

where, since angle displacements α and β in the detection direction with respect to the X and the Y axis are approximately 5° at the most, even if $\cos(\alpha) = 1$ and $\cos(\beta) = 1$, the gain dispersions G1 and G2 can be approximated within an error of about 0.4%. Accordingly, the equations (Expression 7) and (Expression 8) can be approximated as expressed by the following equations (Expression 9) and (Expression 10) respectively:

(Expression 9) $G1 = u1/\omega 1$

(Expression 10) $G2 = v2/\omega 2$.

[0028]

Thus, the gain dispersions G1 and G2 can be calculated by the output values of the yaw and the pitch angular velocity detecting circuit 8 and 9 in the case where predetermined angular velocities are applied to the X and the Y axis. In Figure 2, the G1 and the G2 are calculated by the above method. The output values of the yaw and the pitch angular velocity detecting circuit 8 and 9 are multiplied by the gain adjustment value A1 in the yaw direction proportional to the inverse number of the G1 and the gain adjustment value A2 in the pitch direction proportional to the inverse number of the G2 to correct the gain dispersions. The output values U and V of the yaw and the pitch angular velocity detecting circuit 8 and 9 in which the gain dispersions have been corrected are calculated by the following equations (Expression 11) and (Expression 12):

(Expression 11) $U = A1 \times G1 \times \omega \times \cos(\theta + \alpha)$

(Expression 12) $V = A2 \times G2 \times \omega \times \sin(\theta - \beta)$.

[0029]

The detection angle displacements α and β are calculated by the following equations (Expression 13) and (Expression 14) derived from the equations (Expression 3) and (Expression 5) and the equations (Expression 4) and (Expression 6) respectively:

(Expression 13) $\tan(\alpha) = -(\omega 1/\omega 2) \times (u2/u1)$

(Expression 14) $\tan(\beta) = -(\omega 2/\omega 1) \times (v1/v2)$,

where, since the displacements α and β in the detection direction with respect to the X and the Y axis are approximately 5° at the most, even if $\cos(\alpha) = 1$ and $\cos(\beta) = 1$, approximation is possible within an error of about 0.4%. Accordingly, the equations (Expression 13) and (Expression 14) can be approximated as expressed by the following equations (Expression 15) and (Expression 16) respectively:

(Expression 15) $\sin(\alpha) = -(\omega 1/\omega 2) \times (u2/u1)$

(Expression 16) $\sin(\beta) = -(\omega 2/\omega 1) \times (v1/v2)$.

[0030]

Thus, the angle displacements α and β in the detection direction of the yaw and the pitch angular velocity detecting circuit 8 and 9 can be calculated by the output values of the yaw and the pitch angular velocity detecting circuit 8 and 9 in the case where predetermined angular velocities are applied to the X and the Y axis.

[0031]

The following is a description of a method of correcting the angle displacement of an actual camera at the time of calculating the gain dispersions G1 and G2 and angle displacements α and β using the above method. For the simplicity of description, if the equations (Expression 11) and (Expression 12) are normalized with $A1 \times G1$ taken as 1 and $A2 \times G2$ taken as

1, the output values U and V of the yaw and the pitch angular velocity detecting circuit 8 and 9 after the correction of the gain dispersions G1 and G2 can be represented by the following equations (Expression 17) and (Expression 18):

(Expression 17) $U = \omega \times \cos(\theta + \alpha)$

(Expression 18) $V = \omega \times \sin(\theta - \beta)$.

The angular velocities X and Y in the X and the Y axis direction are calculated by the following equations (Expression 19) and (Expression 20):

(Expression 19) $X = \omega \times \cos(\theta)$

(Expression 20) $Y = \omega \times \sin(\theta)$.

If the equations (Expression 17) and (Expression 18) are rendered independent of θ, the equations can be represented by the following equations (Expression 21) and (Expression 22):

(Expression 21) $X = (\cos(\beta)/\cos(\alpha + \beta)) \times U + (\sin(\alpha)/\cos(\alpha + \beta)) \times V$

(Expression 22) $Y = (\cos(\alpha)/\cos(\alpha + \beta)) \times V + (\sin(\beta)/\cos(\alpha + \beta)) \times U$.

[0032]

Where, since the displacements α and β in the detection direction with respect to the X and the Y axis are approximately 5° at the most, if $\cos(\alpha)$, $\cos(\beta)$ and $\cos(\alpha + \beta)$ are approximated to one respectively, the equations (Expression 21) and (Expression 22) can be approximated as expressed by the

following equations (Expression 23) and (Expression 24) respectively:

(Expression 23) $X = U + \sin(\alpha) \times V$

(Expression 24) $Y = V + \sin(\beta) \times U$,

in other words, if the gain dispersions are calculated by the equations (Expression 9) and (Expression 10) and the sin values of angle displacements are calculated by the equations (Expression 14) and (Expression 15), the gain dispersions G1 and G2 and the angle displacements α and β can be corrected by the equations (Expression 23) and (Expression 24).

[0033]

The correction of the gain dispersions G1 and G2 and the angle displacements α and β is described below with reference to Figure 2. The outputs "u" and "v" of the yaw and the pitch angular velocity detecting circuit 8 and 9 with the gain dispersions G1 and G2 are multiplied by gain adjustment values A1 and A2 respectively to obtain the gain-adjusted outputs U and V. The sum of the output U and the output in which the output V is multiplied by an angle displacement adjustment value $\Delta\alpha$ is taken as X and the sum of the output V and the output in which the output U is multiplied by an angle displacement adjustment value $\Delta\beta$ is taken as Y. Where, the angle displacement adjustment value $\Delta\alpha = \sin(\alpha)$ and $\Delta\beta = \sin(\beta)$. That is to say, the configuration illustrated in Figure 2

provides the angular velocities X and Y in the X and the Y axis direction. After that, the angular velocities X and Y are multiplied by B to obtain target velocities Vc(X) and Vc(Y) at which the vibration-proof lens 13 is shifted in the X and the Y axis direction (hereinafter, referred to as "target velocity of vibration-proof lens"). Where, B is a coefficient which determines a velocity at which the vibration-proof lens 13 is shifted with respect to a predetermined angle velocity (hereinafter, referred to as an "angular-velocity to vibration-proof lens target-velocity converting coefficient." That is to say, multiplying the calculated angular velocities X and Y in each driving axis direction by B calculates the vibration-proof lens target-velocities Vc(X) and Vc(Y) in each direction. After the vibration-proof lens target-velocities Vc(X) and Vc(Y) have been calculated, the vibration-proof lens 13 is shifted at each velocity to enable hand shake on an image surface to be cancelled.

[0034]

(2) An adjustment method using a shaking table sinusoidally varying an angular velocity

In the above description, gain adjustment and angle displacement adjustment can be performed by continuously applying a constant angular velocity to a camera to detect the output values of the yaw and the

pitch angular velocity detecting circuit 8 and 9 during that application. Actually, however, it is very difficult to accurately apply a constant angular velocity to a camera. The reason is that an accurate application of a constant angular velocity to a camera needs to cause the camera to perform uniform rotational motion with the camera fixed at a given distance around at a point. That is why the shaking table 18 is used to apply a sinusoidally varying angular velocity to a camera to perform the gain adjustment and the angle displacement adjustment.

[0035]

One end around the shaking portion of the shaking table 18 is fixed and a properly flattened cam is arranged under around the opposite end thereof. The cam is rotated by a motor to sinusoidally move the shaking portion upward and downward. The shaking table 18 has the mechanisms in two directions. The camera is attached to the table so that the X and the Y axis drive direction of the vibration-proof lens 13 coincide with the shake directions. Actually, there exists a subtle angle displacement between the drive direction of the vibration-proof lens 13 and the shake direction, however, the angle displacement is smaller enough to be negligible than the angle displacement that matters in the present invention.

[0036]

Referring to Figure 4, an embodiment is described below in which a sinusoidal angular velocity is applied to a camera to perform the gain adjustment and the angle displacement adjustment. Figure 4 is a chart illustrating how the gain and the angle displacement are adjusted according to the present invention. Firstly, a sinusoidal angular velocity with a total amplitude $\omega 1$ is applied to a camera in the X axis driving direction of the vibration-proof lens 13 by the shaking table 18. At this point, the maximum and the minimum output value of the yaw angular velocity detecting circuit 8 are taken as u1max and u1min respectively and the maximum and the minimum output value of the pitch angular velocity detecting circuit 9 are taken as v1max and v1min respectively. Secondly, a sinusoidal angular velocity with a total amplitude $\omega 2$ is applied to the camera in the Y axis driving direction of the vibration-proof lens 13 by the shaking table 18. At this point, the maximum and the minimum output value of the yaw angular velocity detecting circuit 8 are taken as u2max and u2min respectively and the maximum and the minimum output value of the pitch angular velocity detecting circuit 9 are taken as v2max and v2min respectively.

[0037]

The gain dispersion at this point can be regarded similar as that in the case where the above constant

angular velocity is applied. If a sinusoidal angular velocity is applied to the camera, the gain dispersions G1 and G2 are calculated as a ratio of the total amplitude of the applied angular velocity and the total amplitude of the output value as represented by the following equations (Expression 25) and (Expression 26) respectively:

(Expression 25) $G1 = (u1max - u1min)/\omega 1$

(Expression 26) $G2 = (v2max - v2min)/\omega 2$.

Therefore, the gain adjustment values A1 and A2 are calculated as values proportional to the inverse numbers of the G1 and the G2 respectively. Alternately, the gain adjustment values A1 and A2 are given as the ratio of the total amplitudes of the outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9 rendered the target value desired to be obtained after the gain adjustment to the total amplitudes $\omega 1$ and $\omega 2$ of the applied angular velocities. If the target total amplitudes of the outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9 are U1 and V1 respectively after the gain adjustment, the gain adjustment values A1 and A2 are calculated by the following equations (Expression 27) and (Expression 28) respectively:

(Expression 27) $A1 = U1/(u1max - u1min)$

(Expression 28) $A2 = V1/(v2max - v2min)$.

[0038]

The angle displacement in the detection direction of the yaw and the pitch angular velocity detecting circuit 8 and 9 may also be regarded similar as that in the case where the above constant angular velocity is applied. If a sinusoidal angular velocity is applied to the camera, the angle displacement is calculated by the following equations (Expression 29) and (Expression 30) respectively:

(Expression 29) $\sin(\alpha) = - f * (\omega 1/\omega 2) \times \{(u2max - u2min)/(u1max - u1min)\}$

(Expression 30) $\sin(\beta) = - c * (\omega 2/\omega 1) \times \{(v1max - v1min)/(v2max - v2min)\}$,

where, "c" and "f" are given by the following equations (Expression 31) and (Expression 32) respectively:

(Expression 31) c = + 1 (v1 is positive at the time of detecting u1max when the angular velocity is applied in the X axis)

c = - 1 (v1 is negative at the time of detecting u1max when the angular velocity is applied in the X axis)

(Expression 32) f = + 1 (u2 is positive at the time of detecting v2max when the angular velocity is applied in the Y axis)

f = - 1 (u2 is negative at the time of detecting v2max when the angular velocity is applied in the Y axis)

[0039]

Since the values of the total amplitudes calculated from the maximum and the minimum value at the time of applying the sinusoidal angular velocity to the camera are always positive, the sign of the angle displacement is unknown. To avoid that, in the equation (Expression 31), if the angular velocity applied in the X axis direction is positive, the output of the pitch angular velocity detecting circuit 9 is the same in sign as that at the time of detecting the maximum output value u1max of the yaw angular velocity detecting circuit 8, so that the sign of angle displacement is detected using the above (as is the case with the equation (Expression 32)). In the present embodiment, although the above method is used to detect the sign of angle displacement for purpose of simplification, the sign of output of an angular velocity detecting circuit in the opposite direction at the time of detecting the minimum value or the sign of the angular velocity applied by the shaking table 18 may be compared with the signs of outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9 to detect the sign of the angle displacement.

[0040]

Here, the problem is that, unless the shaking table 18 is accurately controlled, the above maximum and the minimum value cannot be accurately calculated

when the gain adjustment and the angle displacement adjustment are performed by applying a sinusoidally varying angular velocity to a camera angular velocity using the shaking table 18. This is firstly because if the frequency of the angular velocity applied by the shaking table 18 is varied due to wow and flutter of the drive motor of the shaking table 18, the total amplitudes of the output values of the yaw and the pitch angular velocity detecting circuit 8 and 9 are varied in proportion to the amount of variation, causing an error in a gain adjustment value and an angle displacement adjustment value, and secondly because if the shaking table 18 does not operate smoothly to shake the camera with a high frequency, noises according to the shake are superposed on the output values of the yaw and the pitch angular velocity detecting circuit 8 and 9 to produce an error in the detection of the maximum and the minimum value of the output value of each angular velocity detecting circuit, causing an error in a gain adjustment value and an angle displacement adjustment value. A method of resolving the problems is described below. Incidentally, if the above problem is not found when these adjustments are made using an accurate shaking table, it is needless to say that the above adjustment method is available.

[0041]

(3) An adjustment method using an integral value of an angular velocity

The above adjustment method is performed by the dimension of an angular velocity. The following adjustment method is performed by the dimension of an angle or a position. First, an initial value is set to the gain adjustment values in the yaw and the pitch direction as represented by the following equation (Expression 33) and the angle displacement adjustment values $\Delta\alpha$ and $\Delta\beta$ are cleared as represented by the equation (Expression 34):

(Expression 33) A1 = A2 = A0

(Expression 34) $\Delta\alpha = \Delta\beta = 0$.

This outputs the angular velocities X and Y in the detection directions in which the gain adjustment and the angle displacement correction are not performed in Figure 2. Secondly, the vibration-proof lens target velocities Vc(X) and Vc(Y) in the X and the Y axis direction in which the outputs (the angular velocities X and Y) are multiplied by B are integrated as represented by the following equations (Expression 35) and (Expression 36) respectively, calculating target positions LC (X) and LC (Y) in the X and the Y axis direction of the vibration-proof lens 13:

(Expression 35) $LC\ (X) = \int Vc\ (X)$

(Expression 36) $LC\ (Y) = \int Vc\ (Y)$.

[0042]

On the other hand, the target positions LC (X) and LC (Y) of the vibration-proof lens 13 are preferably calculated by accumulating the target velocities Vc(X) and Vc(Y) at a predetermined time interval instead of the integrals represented by the equations (Expression 35) and (Expression 36) in the case where the outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9 are A/D converted by, for example, the CPU 1 and the subsequent process is controlled using digital values. In this case, the target positions LC (X) and LC (Y) of the vibration-proof lens 13 may be calculated by accumulation.

[0043]

A sinusoidal shake vibration with an angular total-amplitude $\gamma 1$ is applied to the camera in the X axis direction of the vibration-proof lens 13 by the shaking table 18. If the maximum and the minimum value of the target position LC (X) are taken as LCmax(X) and LCmin(X) respectively, and the maximum and the minimum value of the target position LC (Y) are taken as LCmax(Y) and LCmin(Y) respectively, the total amplitudes "a" and "b" of the vibration-proof lens target-positions of the X and the Y axis are calculated from the following equations (Expression 37) and (Expression 38) respectively. In addition, "c" is calculated by a sign of the target position LC (Y) at the time of detecting the LCmax(X) from the equation

(Expression 39):

(Expression 37) a = LCmax(X) - Lcmin(X)

(Expression 38) b = LCmax(Y) - Lcmin(Y)

(Expression 39) c = +1 (LC(Y) is positive at the time of detecting LCmax(X))

C = -1 (LC(Y) is negative at the time of detecting LCmax(X)).

[0044]

A sinusoidal shake vibration with an angular total-amplitude γ2 is applied to the camera in the Y axis driving direction of the vibration-proof lens 13 by the shaking table 18. If the maximum and the minimum value of the target position LC (X) are taken as LCmax(X) and LCmin(X) respectively, and the maximum and the minimum value of the target position LC (Y) are taken as LCmax(Y) and LCmin(Y) respectively, the total amplitudes "d" and "e" of the vibration-proof lens target-positions of the X and the Y axis are calculated from the following equations (Expression 40) and (Expression 41) respectively. In addition, "f" is calculated by a sign of the target position LC (X) at the time of detecting the LCmax(Y) from the equation (Expression 42):

(Expression 40) d = LCmax(X) - Lcmin(X)

(Expression 41) e = LCmax(Y) - Lcmin(Y)

(Expression 42) f = +1 (LC(X) is positive at the time of detecting LCmax(Y))

f = -1 (LC(X) is negative at the time of detecting LCmax(Y)).

[0045]

If the total amplitudes of the vibration-proof lens target positions LC (X) and LC (Y) in the X and the Y axis direction desired to be obtained after gain adjustment are taken as L01 and L02 respectively with respect to the angular total-amplitudes $\gamma1$ and $\gamma2$ applied by the shaking table 18, the gain adjustment values A1 and A2 are calculated by the following equations (Expression 43) and (Expression 44) respectively. Where, L01 and L02 are proportional to the angular total-amplitudes $\gamma1$ and $\gamma2$ and are the total amplitudes of shift of the vibration-proof lens 13 being proper to stop an image with respect to shake-angular total-amplitudes. The value is determined by a photographing optical system and the theoretical value thereof is calculated.

(Expression 43) $A1 = A0 \times L01/a$

(Expression 44) $A2 = A0 \times L02/e$

[0046]

The equations (Expression 43) and (Expression 44) convert the angular velocities represented by the equations (Expression 27) and (Expression 28) to dimensions of the vibration-proof lens target positions being integral values of the angular velocities. The equations (Expression 43) and (Expression 44) calculate

a multiplier by which an initial value A0 of the gain adjustment value is multiplied from the ratio of the vibration-proof lens amplitudes before the gain adjustment to the amplitudes of the vibration-proof lens target positions desired to be obtained in the case where the gain adjustment value is an initial value A0 and the initial value A0 is multiplied by the multiplier to calculate the gain adjustment value.

[0047]

Angle displacement correction amounts $\Delta\alpha$ and $\Delta\beta$ in the detection directions of the yaw and the pitch angular velocity detecting circuit 8 and 9 are calculated by the following equations (Expression 45) and (Expression 46) respectively:

(Expression 45) $\Delta\alpha = \sin(\alpha) = - f * (L01/L02) \times (d/a)$

(Expression 46) $\Delta\beta = \sin(\beta) = - c * (L02/L01) \times (b/e)$,

the equations (Expression 45) and (Expression 46) convert the angular velocities represented by the equations (Expression 29) and (Expression 30) to dimensions of the vibration-proof lens target positions being integral values of the angular velocities.

[0048]

Performing the gain adjustment and the angle displacement adjustment by integral values of the outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9 using the above method hardly varies the angular amplitude of the shaking table 18

even if the frequency of the shaking table 18 varies in some degree. Even if a vibration noise is slightly superposed on the outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9 at the time of applying vibration by the shaking table 18, calculation is performed from the integral values of the outputs, so that the adjustment can be made substantially independently of the influence of the noise.

[0049]

An embodiment of adjustment process of an actual camera is described below. The adjustment process is divided into a communication-tool adjustment process performed on the communication tool side and a camera communication-mode process formed on the camera side. The outline of the general adjustment process is described. As illustrated in Figure 1, the CPU 1 of the camera is electrically connected to the communication tool 15 to perform the adjustment process of the camera. In the following description, motors 4 and 5 are controlled by a pulse width modulation (PWM). In general, the PWM control is a method in which an energizing time is made variable during a certain period of time, that is to say, duty at which the motors 4 and 5 are turned on is made variable, thereby performing speed control. Figure 7 is a flow chart illustrating one embodiment of a communication

adjustment process performed by the communication tool 15. Figure 8 is a flow chart following Figure 7. Figure 9 is a flow chart following Figure 8. In Figures 7 to 9, the communication tool 15 inspects whether the vibration-proof lens shifting mechanism normally operates at steps S602 to S607 and performs the gain adjustment and the detection angle displacement adjustment of the yaw and the pitch angular velocity detecting circuit 8 and 9 at steps S608 to S624. In addition, the communication tool 15 performs the total inspection of vibration-proof controllability at steps S625 to S646.

[0050]

Figure 10 is a flow chart illustrating one embodiment of the communication-mode process performed by the CPU 1 of the camera. The CPU 1 of the camera starts the communication-mode process of the camera according to instructions from the communication tool 15. The CPU 1 performs, for example, a vibration-proof lens resetting process at step S704 and a vibration-proof-control starting process at step S709 in response to instructions from the communication tool 15.

[0051]

(1) Process on the camera side

The communication-mode process on the camera side is described in detail with reference to Figure 10. When the communication tool process is started at step

S600 in Figure 7, the communication tool 15 transmits an instruction to perform the communication-mode process to the CPU 1 of the camera at the following step S601. Thereby, the CPU 1 of the camera starts the communication-mode process at step S700 in Figure 10 and proceeds to the following step S701. At step S701, the initial value A0 is set to the angular velocity gain adjustment values A1 and A2 by the equation (Expression 33). The angle displacement adjustment values $\Delta\alpha$ and $\Delta\beta$ are cleared by the equation (Expression 34) at the following step S702 and the process proceeds to step S703. The processes S703 to S718 are branched depending on the kind of instruction from the communication tool 15. At step S703, a determination is made as to whether a vibration-proof lens resetting instruction is issued. If the instruction is issued, the vibration-proof lens resetting process (refer to Figure 11) is performed at step S704 and the process returns to step S703. If the instruction is not issued, the process proceeds to step S705. At step S705, a determination is made as to whether a vibration-proof lens centering instruction is issued. If the instruction is issued, a vibration-proof lens centering process (refer to Figure 12) is performed at step S706 and the process returns to step S703. If the instruction is not issued, the process proceeds to step S707.

[0052]

At step S707, a determination is made as to whether a vibration-proof adjustment starting instruction is issued. If the instruction is issued, a vibration-proof-control starting process (refer to Figure 13) is performed at step S709 and the process returns to step S703. If the instruction is not issued, the process proceeds to step S708. At step S708, a determination is made as to whether a vibration-proof control starting instruction is issued. If the instruction is issued, a vibration-proof-control starting process is performed at step S709 and the process returns to step S703. If the instruction is not issued, the process proceeds to step S710. At step S710, a determination is made as to whether a vibration-proof adjustment ending instruction is issued. If the instruction is issued, a vibration-proof-control timer interrupt process is disabled at step S712, the vibration-proof-control is ended and the process returns to step S703. If the instruction is not issued, the process proceeds to step S711. At step S711, a determination is made as to whether a vibration-proof control ending instruction is issued. If the instruction is issued, a vibration-proof-control timer interrupt process is disabled at step S712, the vibration-proof-control is ended and the process returns to step S703. If the instruction is not issued,

the process proceeds to step S713.

[0053]

At step S713, a determination is made as to whether a data read instruction is issued. If the instruction is issued, data specified by the communication tool 15 is transferred to the communication tool 15 at step S714 and the process returns to step S703. If the instruction is not issued, the process proceeds to step S715. At step S715, a determination is made as to whether a data write instruction is issued. If the instruction is issued, data transferred by the communication tool 15 is written in data specified by the communication tool 15 at step S716 and the process returns to step S703. If the instruction is not issued, the process proceeds to step S717. At step S717, a determination is made as to whether an E2PROM write instruction is issued. If the instruction is issued, data transferred by the communication tool 15 is written in data in the E2PROM specified by the communication tool 15 at step S718 and the process returns to step S703. If the instruction is not issued, the process proceeds to step S719. At step S719, a determination is made as to whether a communication mode release instruction is issued. If the instruction is issued, the communication mode process of the camera is ended at step S720. If the instruction is not issued, the process proceeds to step

S703. As described above, according to the instruction of the communication tool 15, the camera performs processes corresponding to the instruction.

[0054]

Figure 11 is a flow chart illustrating one embodiment of the vibration-proof lens resetting process at step S704 in Figure 10. The process proceeds to step S800 from step S704 to start the vibration-proof lens resetting process. At step S801, the vibration-proof lens resetting timer interrupt process (refer to Figure 14) is permitted to start resetting the vibration-proof lens 13. At step S802, the process waits for a predetermined time (for example, 10 ms) and proceeds to step S803. At step S803, a determination is made as to whether the vibration-proof lens velocity VR(X) of the X axis is equal to a predetermined value or less, that is to say, the resetting drive of the vibration-proof lens of the X axis is ended. If the velocity is equal to a predetermined value or less, the process proceeds to step S804. If not, the process returns to step S803. At step S804, a determination is made as to whether the vibration-proof lens velocity VR(Y) of the Y axis is equal to a predetermined value or less, that is to say, the resetting drive of the vibration-proof lens of the Y axis is ended. If the velocity is equal to a predetermined value or less, the process proceeds to

step S805 to end the resetting process of the vibration-proof lens. If not, the process returns to step S803.

[0055]

Therefore, the processes at steps S803 and S804 are repeated until the vibration-proof lens resetting drive process of both the X and the Y axis is ended. After the process of both the axes is ended, the process is ended at step S805. Whether the vibration-proof lens resetting drive is ended is determined based on whether the velocities VR(X) and VR(Y) of the vibration-proof lens 13 become equal to substantially zero when the vibration-proof lens 13 reaches the reset end being one end of the control range thereof. The reason the process waits for a predetermined time at step S802 is that an erroneous determination is prevented at the processes S803 and S804 caused by the rise of the velocities VR(X) and VR(Y) of the vibration-proof lens 13 from substantially zero at the initial stage of reset drive thereof.

[0056]

Figure 14 is a flow chart illustrating one embodiment of the vibration-proof lens resetting timer interrupt process at step S801 in Figure 11. Practically, two vibration-proof lens resetting timer interrupt processes for the X and the Y axis are performed, but both processes are the same, so that the

process only on the X axis side is described and the process on the Y axis side is omitted. The process is repeated at a predetermined interval (for example, 1 ms). When the present vibration-proof lens resetting timer interrupt process is permitted at step S801, the vibration-proof lens position LR(X) set at the preceding vibration-proof lens resetting timer interrupt process is set to LR'(X) at step S1101. The position of the X axis of the vibration-proof lens 13 detected by the X axis lens position detecting circuit 6 is set to LR(X) at step S1102. At step S1103, LR'(X) is subtracted from LR(X) to calculate variation in position of the vibration-proof lens 13 during a predetermined time period, i.e., the velocity VR(X) of the vibration-proof lens 13 in the X axis direction. At the following step S1104, the motor 4 is driven at a predetermined drive duty to drive the vibration-proof lens 13 to a reset position in the X axis direction. The present vibration-proof lens resetting timer interrupt process is ended at step S1105.

[0057]

Figure 12 is a flow chart illustrating one embodiment of the vibration-proof lens centering process at step S706 in Figure 10. The vibration-proof lens centering process drives the vibration-proof lens 13 to a center position LS. The process proceeds to step S900 from step S706 to start process. At step

S901, there are cleared a vibration-proof lens stop FLG and FLGs to be set if abnormality is detected (such as a vibration-proof lens centering time-out abnormality FLG, an X and a Y axis vibration-proof lens motion abnormality FLG and an X and a Y axis vibration-proof lens position detection abnormality FLG). At the following step S902, a vibration-proof lens centering process interrupt time-out time is set. The time to be set here refers to such a time that the vibration-proof lens 13 is surely driven to the center position within the set time unless any abnormality is generated after the centering process has started.

[0058]

At step S903, the vibration-proof lens centering timer interrupt process (refer to Figure 15) is permitted to start a vibration-proof lens centering control. At step S904, the process waits for a predetermined time. At step S905, there are cleared the maximum values VRmax (X) and VRmax (Y) of each of velocities of the X and the Y axis of the vibration-proof lens 13 and the minimum values VRmin (X) and VRmin (Y) of each of velocities of the X and the Y axis thereof.

[0059]

The reason the process waits for a predetermined time at step S904 is described below. In general, the X and the Y axis lens position detecting circuit 6 and

7 use such a configuration that, for example, variation in position of the vibration-proof lens 13 is detected by the number of counts of interrupter signal pulse. In the above detection method, the interrupter signal is a discrete signal, so that the number of pulses entering during the predetermined time or the inverse number of period of the interrupter signal can detect the vibration-proof lens velocity VR. However, at the beginning of start of the centering control of the vibration-proof lens 13, an accurate vibration-proof lens velocity cannot be detected or an impossible high value can be detected. For that reason, even if the interrupter is used, the process waits for a predetermined time period after the centering control has started. After an accurate vibration-proof lens velocity has been calculated, there are cleared VRmax (X), VRmax (Y), VRmin (X) and VRmin (Y). Incidentally, a waiting time at step S904 is usually set to about 5 ms to about 10 ms. VRmax (X), VRmax (Y), VRmin (X) and VRmin (Y) are detected by the vibration-proof lens centering timer interrupt process (Figure 15).

[0060]

At step S906, a determination is made as to whether a vibration-proof lens centering process interrupt timer set at step S902 is timed out, that is to say, whether a predetermined time period has passed after the centering control of the vibration-proof lens

13 was started. If the time has passed, it is determined as abnormal and the process proceeds to step S907 to set the vibration-proof lens centering time-out abnormality FLG and proceeds to step S918. On the other hand, if the time has not passed, the process proceeds to step S908 to determine as to whether the VR max(X) is equal to a predetermined value or less. If the value is equal to the predetermined value or less, it is determined as abnormal in motion in the X axis direction of the vibration-proof lens 13. The process proceeds to step S909 to set the X axis vibration-proof lens motion abnormality FLG and proceeds to step S918. On the other hand, if the value is not equal to the predetermined value or less, the process proceeds to step S910.

[0061]

At step s910, a determination is made as to whether the VR max(Y) is equal to a predetermined value or less. If the value is equal to the predetermined value or less, it is determined as abnormal in motion in the Y axis direction of the vibration-proof lens 13. The process proceeds to step S911 to set the Y axis vibration-proof lens motion abnormality FLG and proceeds to step S918. On the other hand, if the value is not equal to the predetermined value or less, the process proceeds to step S912. The processes at steps S908 and S910 determine the abnormality of motion of

the vibration-proof lens 13 using the maximum values VRmax(X) and VRmax(Y) of the vibration-proof lens velocities becoming small when the vibration-proof lens 13 is out of order. The maximum values VRmax(X) and VRmax(Y) may be determined based on whether the vibration-proof lens velocities VR(X) and VR(Y) are equal to a predetermined value or less.

[0062]

At step S912, a determination is made as to whether the VRmin(X) is equal to a predetermined value or less. If the value is equal to the predetermined value or less, it is determined as abnormal in an X axis lens position detection. The process proceeds to step S913 to set the X axis vibration-proof lens position detection abnormality FLG and proceeds to step S918. On the other hand, if the value is not equal to the predetermined value or less, the process proceeds to step S914. At step S914, a determination is made as to whether the VRmin(Y) is equal to a predetermined value or less. If the value is equal to the predetermined value or less, it is determined as abnormal in an Y axis lens position detection. The process proceeds to step S915 to set the Y axis vibration-proof lens position detection abnormality FLG and proceeds to step S918. On the other hand, if the value is not equal to the predetermined value or less, the process proceeds to step S916. The processes at

steps S912 and S914 determine the abnormality of output of the X and the Y axis lens position detecting circuit 6 and 7 using an abnormality value to be set to the VRmin(X) and the VRmin(Y) when the vibration-proof lens velocities VR(X) and VR(Y) being the outputs of the X and the Y axis lens position detecting circuit 6 and 7 are calculated as abnormal values and impossible small values (for example, values with negative signs) and detected in the vibration-proof lens centering timer interrupt (Figure 15). The minimum values VRmin(X) and VRmin(Y) may be determined based on whether the vibration-proof lens velocities VR(X) and VR(Y) are equal to a predetermined value or less.

[0063]

At step S916, a determination is made as to whether the operation of the vibration-proof lens 13 in the X axis direction of is stopped. If the operation is stopped, the process proceeds to step S917. If the operation is not stopped, the process returns to step S906. The determination as to whether the operation of the vibration-proof lens 13 is stopped is made by the X axis vibration-proof lens stop FLG. The X axis vibration-proof lens stop FLG is set when the X axis vibration-proof lens position LR(X) set at the vibration-proof lens centering timer interrupt process reaches the front of a predetermined value Lstop of the center position LS. At step S917, as is the case with

step S916, a determination is made as to whether the operation of the vibration-proof lens 13 in the Y axis direction is stopped. If the operation is stopped, the process proceeds to step S918. If the operation is not stopped, the process returns to step S906. The determination as to whether the operation of the vibration-proof lens 13 is stopped is made by the Y axis vibration-proof lens stop FLG as is the case with above. The Y axis vibration-proof lens stop FLG is set when the Y axis vibration-proof lens position LR(Y) set at the vibration-proof lens centering timer interrupt process reaches the front of a predetermined value Lstop of the center position LS.

[0064]

The processes at steps S916 and S917 repetitively execute the processes at the steps S906 to S917 until the positions of the vibration-proof lens 13 both in the X and the Y axis reach the front of the predetermined value Lstop of the center position LS, and the process proceeds to step S918 when both axes reach a predetermined value. At step S918, the centering timer interrupt process of the vibration-proof lens 13 is disabled. This renders the motors 4 and 5 into a short-brake state to stop the vibration-proof lens 13 in both directions and the process proceeds to step S919 to end the vibration-proof lens centering process.

[0065]

Figure 15 is a flow chart illustrating one embodiment of the vibration-proof lens centering timer interrupt process at step S903 in Figure 12. Practically, two vibration-proof lens centering timer interrupt processes for the X and the Y axis are performed, but both processes are the same, so that the process only on the X axis side is described and the process on the Y axis side is omitted. The process is repeated at a predetermined time interval (for example, 1 ms) by permitting the vibration-proof lens centering timer interrupt process at step S903. The vibration-proof lens position LR(X) set by the preceding vibration-proof lens centering timer interrupt process is set to LR'(X) at step S1201. The position of the X axis of the vibration-proof lens 13 detected by the X axis lens position detecting circuit 6 is set to LR(X) at step S1202. At step S1203, LR'(X) is subtracted from LR(X) to calculate variation in position of the vibration-proof lens 13 during a predetermined time period, i.e., the velocity VR(X) of the vibration-proof lens 13 in the X axis direction.

[0066]

At step S1204, a determination is made as to whether the vibration-proof lens velocity VR(X) in the X axis direction is greater than VRmax(X). If the velocity is greater, the process proceeds to step S1205

to set VR(X) to VRmax(X) and proceeds to step S1206. On the other hand, if not, the process proceeds to step S1206. At step S1206, a determination is made as to whether the vibration-proof lens velocity VR(X) in the X axis direction is smaller than VRmin(Y). If the velocity is smaller, the process proceeds to step S1207 to set VR(X) to VRmin(X) and proceeds to step S1208. On the other hand, if not, the process proceeds to step S1208. The processes at steps S1204 to S1207 detect the maximum value VRmax(X) and the minimum value VRmin(X) of the vibration-proof lens velocity VR(X) in the X axis direction.

[0067]

At step S1208, whether the vibration-proof lens position LR(X) in the X axis direction is driven to the front of the predetermined value Lstop of the center position LS is determined based on whether LR(X) + Lstop are equal to or greater than LS. If LR(X) is driven to the position, the process proceeds to step S1209 to set the X axis vibration-proof lens stop FLG. At step S1210, the motor 4 is rendered a short-brake state and the process proceeds to step S1214 to end the vibration-proof lens centering timer interrupt process. On the other hand, if LR(X) is not yet driven to the position, the process proceeds to step S1211. At step S1211, the target velocity VC(X) of the vibration-proof lens in the X axis direction is calculated by the

following equation (Expression 47). At step S1212, a drive duty is calculated by the following equation (Expression 48):

(Expression 47) $VC(X) = K10 \times \{LS - LR(X)\} + Voffset$

(Expression 48) Centering drive duty $= K1 \times VC(X) + K2 \times \{VC(X) - VR(X)\} \pm Doffset$.

[0068]

The equation (Expression 47) represents that the target velocity VC(X) of the vibration-proof lens in the X axis direction is obtained by adding a predetermined velocity Voffset to a velocity according to a difference between the vibration-proof lens position LR(X) in the X axis direction detected by the X lens position detecting circuit 6 and the center position LS. The drive duty driving the motor 4 is represented by the equation (Expression 48) until the vibration-proof lens position LR(X) in the X axis direction reaches the front of the predetermined value Lstop of the center position LS and after that the motor 4 is rendered into a short brake state. The equation (Expression 48) obtains the drive duty such that a duty in which the target velocity VC(X) of the vibration-proof lens in the X axis direction is multiplied by a predetermined coefficient K1 is added to a duty calculated by multiplying a difference between the VC(X) and the vibration-proof lens velocity VR(X) in the X axis direction by a predetermined

coefficient K2 and that if the value is positive, Doffset is further added and if the value is negative, Doffset is subtracted. Thereby, the vibration-proof lens 13 is controlled by the vibration-proof lens target velocity VC(X) substantially set in the X axis direction.

[0069]

At step S1213, the motor 4 is driven at the calculated drive duty to drive the vibration-proof lens 13 in the direction of the center position LS of the X axis and the process proceeds to step S1214 to end the process.

[0070]

The centering control of the vibration-proof lens 13 is described below. Figure 6 is a chart describing the centering control in the X axis direction of the vibration-proof lens 13. In Figure 6, the centering drive of the vibration-proof lens 13 starts at D1 and an attempt is made to control the vibration-proof lens 13 to the set target velocity VC(X) of the vibration-proof lens. The vibration-proof lens velocity VR(X) in the X axis direction gradually increases based on a relationship of time constant of the vibration-proof control system including the motor 4 and the vibration-proof lens shifting mechanism and reaches the maximum value at D2. Between D2 and D3 being the front of Lstop of the center position LS, the target velocity

VC(X) is set by a linear line calculated from the equation (Expression 47). The vibration-proof lens 13 is controlled in velocity along the linear line. The vibration-proof lens velocity VR(X) gradually decreases as it gets close to the center position LS. At D3, the motor 4 is rendered into a short brake state and the vibration-proof lens 13 finally stops at D4 in the vicinity of the center position LS.

[0071]

Thus, the execution of the vibration-proof lens centering process drives the vibration-proof lens 13 to the vicinity of the target center position LS, detects the maximum value of the vibration-proof lens velocity in the X axis direction during the drive and stores it as VRmax(X). The maximum value VRmax(X) varies according to mobility of the vibration-proof lens shifting mechanism. If the mechanism has a failure for some reason, the maximum value VRmax(X) decreases to set the X axis vibration-proof lens motion abnormality FLG. If the X axis lens position detecting circuit 6 has an abnormality to calculate an impossible vibration-proof lens velocity VR(X) at the time of the centering control and the velocity is a negative value, for example, the value is stored in VRmin(X) and at the same time the X axis vibration-proof lens position detection abnormality FLG is set.

[0072]

The Y axis vibration-proof lens centering timer interrupt process is performed similarly with the above process in the X axis direction. That is to say, the maximum value of the vibration-proof lens velocity in the Y axis direction at that point is stored in VRmax(Y) and if each abnormality is found, each abnormality FLG is set (such as the Y axis vibration-proof lens motion abnormality FLG and the Y axis vibration-proof lens position detection abnormality FLG). If both axes do not reach the center position LS after the control has been continued for a predetermined period of time, the vibration-proof lens time-out abnormality FLG is set.

[0073]

Figure 13 is a flow chart illustrating one embodiment of the vibration-proof-control starting process at step S709 in Figure 10. This is a process in which the maximum and the minimum value of the X and the Y axis vibration-proof lens target position, the maximum and the minimum value of the vibration-proof lens position and control error are detected to move the vibration-proof lens 13 to each direction according to the outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9, starting the vibration-proof control process for suppressing hand shake on an image surface. The process proceeds to step S1000 from step S709 to start the present process.

At step S1001, the current vibration-proof lens positions are detected from the outputs of the X and the Y axis lens position detecting circuit 6 and 7 and set to the vibration-proof lens target position LC(X) and LC(Y) of the X and the Y axis respectively. At step S1002, the current vibration-proof lens positions detected by the outputs of the X and the Y axis lens position detecting circuit 6 and 7 are set to the maximum values LCmax(X) and LCmax(Y) and the minimum values LCmin(X) and LCmin(Y) of the vibration-proof lens target position LC(X) and LC(Y) of the X and the Y axis respectively.

[0074]

At step S1003, the current vibration-proof lens positions detected by the outputs of the X and the Y axis lens position detecting circuit 6 and 7 are set to the maximum values LRmax(X) and LRmax(Y) and the minimum values LRmin(X) and LRmin(Y) of the vibration-proof lens position of the X and the Y axis respectively. At step S1004, the maximum values ΔLmax(X) and ΔLmax(Y) and the minimum values ΔLmin(X) and ΔLmin(Y) of the vibration-proof lens position error of the X and the Y axis are cleared. At step S1005, the vibration-proof-control timer interrupt process (Figure 16) is permitted to start the vibration-proof control. At step 1006, the present vibration-proof-control starting process is ended.

[0075]

Figure 16 is a flow chart illustrating one embodiment of the vibration-proof-control timer interrupt process in which the vibration-proof-control timer interrupt process is permitted by the vibration-proof-control starting process at step S1005 in Figure 13 to perform the process at a predetermined time interval. The process starts at step S1300. Practically, two vibration-proof-control timer interrupt processes for the X and the Y axis are performed, but both processes are the same, so that the process only on the X axis side is described and the process on the Y axis side is omitted. The process is repeated at a predetermined time interval (for example, 1 ms). At step S1301, the vibration-proof lens position LR(X) set by the preceding vibration-proof-control timer interrupt process is set to LR’(X). At step S1302, the position of the X axis of the vibration-proof lens 13 detected by the X axis lens position detecting circuit 6 is set to LR(X).

[0076]

At step S1303, the maximum and the minimum values of the vibration-proof lens position are detected. Figure 17 is a flow chart illustrating one embodiment of the process for detecting the maximum and the minimum values of the vibration-proof lens positions. The process proceeds to step S1400 in Figure 17 from

step S1303. At step S1401, a determination is made as to whether the X axis vibration-proof lens position LR(X) is larger than LRmax(X). If it is larger, the process proceeds to step S1402 to set LR(X) to LRmax(X) and the process proceeds to step S1403. If not, the process proceeds to step S1403. At step S1403, a determination is made as to whether the X axis vibration-proof lens position LR(X) is smaller than LRmin(X). If it is smaller, the process proceeds to step S1404 to set LR(X) to LRmin(X) and the process proceeds to step S1405. If not, the process proceeds to step S1405. The process is ended at steps 1405. The above process detects the maximum and the minimum values of the vibration-proof lens position LR(X) in the X axis direction as LRmax(X) and LRmin(X) respectively.

[0077]

The process proceeds to step S1304 in Figure 16 from step s1405. At step S1304, LR′(X) is subtracted from LR(X) to calculate variation in position of the vibration-proof lens 13 in the X axis direction during a predetermined time period, i.e., the velocity VR(X) of the vibration-proof lens 13 in the X axis direction. At step S1305, the output of the yaw angular velocity detecting circuit 8 is A/D converted and the value is set as “u.” At step S1306, “u” is multiplied by a gain adjustment value A1 to set it as “U,” calculating a

gain-adjusted angle velocity in the yaw direction. At step S1307, as represented by the equation (Expression 23), the gain-adjusted angular velocity value V in the other pitch direction multiplied by the angle displacement adjustment value $\Delta\alpha$(= sin α) is added to "U" to calculate the output X in which an angle displacement is corrected.

[0078]

Where, "V" is a gain-adjusted angle velocity value calculated in the vibration-proof-control timer interrupt process in the Y axis being the other axis. Strictly speaking, the present vibration-proof-control timer interrupt processes in both the X and the Y axis cannot be performed at the same time, so that sampling timings at which the outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9 are A/D converted are different from each other. However, the amount of "V" which varies during displacement between the timings is very small and negligible.

[0079]

At step S1308, the output X calculated at step S1307 is multiplied by the angular-velocity to vibration-proof lens target-velocity converting coefficient B to calculate the X axis vibration-proof lens target velocity VC(X). At step S1309, the target velocity VC(X) is added to the X axis vibration-proof lens target position LC(X) to set LC(X). The target

velocity VC(X) is accumulated at a predetermined time interval to enable the vibration-proof lens target position LC(X) to be calculated. Since the target position LC(X) is set at the timing at step S1001 in Figure 13, the vibration-proof lens target velocity VC(X) is accumulated while the vibration-proof-control timer interrupt process is permitted with the timing as an initial value to continue calculating the vibration-proof lens target position LC(X).

[0080]

At step S1310, the maximum and the minimum values of the vibration-proof lens target position are detected. Figure 18 is a flow chart illustrating one embodiment of a process for detecting the maximum and the minimum values of the vibration-proof lens target position. The process proceeds to step S1500 in Figure 18 from step S1310. At step S1501, a determination is made as to whether the X axis vibration-proof lens target position LC(X) is greater than LCmax(X). If it is greater, the process proceeds to step S1502 to set LC(X) to LCmax(X). At step S1503, the sign of the vibration-proof lens target velocity LC(Y) of the Y axis being the other axis is held and the process proceeds to step S1504. At step S1501, if it is not greater, the process proceeds to step S1504.

[0081]

At step S1504, a determination is made as to

whether the X axis vibration-proof lens target position LC(X) is smaller than LCmin(X). If it is smaller, the process proceeds to step S1505 to set LC(X) to LCmin(X) and proceeds to step S1506. If it is not smaller, the process proceeds to step S1506. The process ends at step S1506. The process detects the maximum and the minimum values of the vibration-proof lens target position LC(X) in the X axis direction in LCmax(X) and LCmin(X) respectively and the sign of the vibration-proof lens target position LC(Y) in the other axis at the time of detecting the maximum value can be obtained.

[0082]

The process proceeds to step S1311 in Figure 16 from step S1506. At step S1311, the vibration-proof lens position LR(X) is subtracted from the X axis vibration-proof lens target position LC(X) to calculate the vibration-proof lens position error ΔL(X). The process proceeds to step S1312 to detect the maximum and the minimum values of the vibration-proof lens position error. Figure 19 is a flow chart illustrating one embodiment of a process for detecting the maximum and the minimum values of the vibration-proof lens position error. The process proceeds to step S1600 in Figure 19 from step S1312. At step S1601, a determination is made as to whether the X axis vibration-proof lens position error ΔL(X) is greater than ΔLmax(X). If it is greater, the process proceeds

to step S1602 to set $\Delta L(X)$ to $\Delta Lmax(X)$ and proceeds to step S1603. If it is not greater, the process proceeds to step S1603. At step S1603, a determination is made as to whether the X axis vibration-proof lens position error $\Delta L(X)$ is smaller than $\Delta Lmin(X)$. If it is smaller, $\Delta L(X)$ is set to $\Delta Lmin(X)$ at step S1604 and proceeds to step S1605. If it is not smaller, the process proceeds to step S1605 to end the process. The process detects the maximum and the minimum values of the vibration-proof lens position error $\Delta L(X)$ in the X axis direction in $\Delta Lmax(X)$ and $\Delta Lmin(X)$ respectively.

[0083]

The process proceeds to step S1313 in Figure 16 from step S1605. At step S1313, a drive duty at which the motor 4 is driven under the vibration-proof control is calculated. The drive duty is calculated from, for example, the equation (Expression 48) used at the time of the centering control. At step S1314, a determination is made as to whether a vibration-proof adjustment is performed. If no, the process proceeds to step S1315 to drive the motor 4 at the drive duty calculated at step S1313. If the vibration-proof adjustment is performed, the process proceeds to step S1316 (without driving the motor 4) to end the present vibration-proof-control timer interrupt process.

[0084]

(2) Process on the communication tool side

Referring to Figures 7 to 9, there are described the total inspection of the vibration-proof lens shifting mechanism, the gain adjustment and the detection angle displacement adjustment of the yaw and the pitch angular velocity detecting circuit 8 and 9 and the total inspection of a vibration-proof controllability which are performed on the communication tool side. The start of the present process at step S601 sets the camera to the communication mode by a known method. This setting starts the communication-mode process of the camera executed by the CPU 1 illustrated in Figure 10. The following processes from steps S602 to S607 inspect the vibration-proof lens shifting mechanism. At step S602, a vibration-proof lens resetting instruction is issued to the CPU 1. The CPU 1 of the camera drives the vibration-proof lens 13 to a predetermined resetting position at step S704 in Figure 10 in response to the instruction. At step S603, a vibration-proof lens centering instruction is issued to drive the vibration-proof lens 13 to the center position LS. At step S604, the CPU 1 reads the maximum values VRmax(X) and VRmax(Y) of the vibration-proof lens velocities of the X and the Y axis detected at the vibration-proof lens centering at step S603 and centering abnormality data (such as a vibration-proof lens centering time-out abnormality FLG, an X and a Y axis vibration-proof lens

motion abnormality FLG and an X and a Y axis vibration-proof lens position detection abnormality FLG) using the data read instruction.

[0085]

At step S605, a determination is made as to whether the maximum value VRmax(X) is equal to or greater than a predetermined value. If it is equal to or greater than the predetermined value, the process proceeds to step S606. If not, the process proceeds to step S646 (refer to Figure 9) and determines that the mechanism is defective. The process proceeds to step S647. At step S606, a determination is made as to whether the maximum value VRmax(Y) is equal to or greater than a predetermined value. If it is equal to or greater than the predetermined value, the process proceeds to step S607. If not, the process proceeds to step S646, similarly to the above, and determines that the mechanism is defective. At step S607, a determination is made by the centering abnormality data as to whether the centering is abnormal. If the centering is not abnormal, in other words, if any one of the abnormal FLGs is not set, the process proceeds to step S608. If at least one of the abnormal FLGs is set, similarly to the above, the process proceeds to step S646 and determines that the mechanism is defective.

[0086]

Thus, centering the vibration-proof lens 13 and detecting the maximum value of the vibration-proof lens velocity during the centering control or each abnormality through the above processes at steps S603 to S607 and S646 enable the vibration-proof lens shifting mechanism to be determined defective if the motion of the vibration-proof lens 13 is abnormal in the X and the Y axis direction or the output of the X and the Y axis lens position detecting circuit 6 and 7 is abnormal for some reason.

[0087]

The processes at steps S608 to S624 perform the gain adjustment and the detection angle displacement adjustment of the yaw and the pitch angular velocity detecting circuit 8 and 9. The gain adjustment values A1 and A2 held in the CPU 1 at the timing at step S608 are the initial value A0 set at step S700 in Figure 10. The angle displacement adjustment value $\Delta\alpha$ and $\Delta\beta$ are the initial value 0 written at step S702 in Figure 10. At step S608, the application of vibration in the X axis direction is started. This vibrates the shaking table 18. The vibration is sinusoidal and has a predetermined angular amplitude in the X axis direction. At step S609, the vibration-proof adjustment starting instruction is issued to the CPU 1. The CPU 1 executes the vibration-proof-control starting process according to the instruction at step S609 and based on step S709

in Figure 10. The vibration-proof-control timer interrupt process illustrating in Figure 16 continues detecting the maximum values LCmax(X) and LCmax(Y) and the minimum values LCmin(X) and LCmin (Y) of the vibration-proof lens target positions and signs of LC(Y) and LC(X) at the time of detecting LCmax(X) and LCmax(Y) respectively. Since the execution is determined as the vibration-proof adjustment at step S1314 in Figure 16, the motor is not driven, so that the vibration-proof lens 13 is not driven either.

[0088]

At step S610, the process waits for a predetermined period of time. At step S611, the vibration-proof adjustment ending instruction is issued to the CPU 1. The CPU 1 disables the vibration-proof-control timer interrupt process at step S712 in Figure 10 to end the vibration-proof control. At step S612, vibration in the X axis direction by the shaking table 18 is ended. The wait at step 610 is a time during which each of the maximum and the minimum value of the vibration-proof lens target position can be detected at least once at steps S609 to S611. At step S613, using the data read instruction, LCmax(X), LCmax(Y), LCmin(X) and LCmin (Y) and the signs of the LC(Y) and LC(X) each at the time of detecting LCmax(X) and LCmax(Y) detected by the CPU 1 are read from the CPU 1. At step S614, the total amplitudes “a,” “b” and “c” of the vibration-

proof lens target positions of the X and the Y axis are calculated using the equations (Expression 37), (Expression 38) and (Expression 39).

[0089]

The process proceeds to step S615 in Figure 8. At step S615, the shaking table 18 is vibrated. The vibration is sinusoidal and has a predetermined angular amplitude in the Y axis direction. At step S616, the vibration-proof adjustment starting instruction is issued to the CPU 1. The CPU 1 executes the vibration-proof-control starting process according to the instruction at step S616 and based on step S709 in Figure 10. The vibration-proof-control timer interrupt process illustrating in Figure 16 continues detecting the maximum values LCmax(X) and LCmax(Y) and the minimum values LCmin(X) and LCmin (Y) of the vibration-proof lens target positions and signs of LC(Y) and LC(X) at the time of detecting LCmax(X) and LCmax(Y) respectively. Since the execution is not determined as the vibration-proof adjustment at step S1314 in Figure 16, the motor is not driven, so that the vibration-proof lens 13 is not driven either.

[0090]

At step S617, the process waits for a predetermined period of time. At step S618, the vibration-proof adjustment ending instruction is issued to the CPU 1. The CPU 1 disables the vibration-proof-

control timer interrupt process at step S712 in Figure 10 to end the vibration-proof control. At step S619, vibration in the Y axis direction by the shaking table 18 is ended. The wait at step 617 is a time during which each of the maximum and the minimum value of the vibration-proof lens target position can be detected at least once at steps S616 to S618. At step S620, using the data read instruction, LCmax(X), LCmax(Y), LCmin(X) and LCmin (Y) and the signs of the respective LC(Y) and LC(X) at the time of detecting LCmax(X) and LCmax(Y) detected by the CPU 1 are read from the CPU 1. At step S621, the total amplitudes "d," "e" and "f" of the vibration-proof lens target positions of the X and the Y axis are calculated using the equations (Expression 40), (Expression 41) and (Expression 42).

[0091]

At step S622, the gain adjustment values A1 and A2 of outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9 are calculated using the equations (Expression 43) and (Expression 44). At step S623, the detection angle displacement adjustment values $\Delta\alpha$ and $\Delta\beta$ of the yaw and the pitch angular velocity detecting circuit 8 and 9 are calculated by the equations (Expression 45) and (Expression 46). At step S624, the E2PROM write instruction is issued. The gain adjustment values A1 and A2 and the detection angle displacement adjustment values $\Delta\alpha$ and $\Delta\beta$ are

written in the E2PROM. The above processes at steps S608 to S624 allow performing the gain adjustment and the detection angle displacement adjustment of the yaw and the pitch angular velocity detecting circuit 8 and 9.

[0092]

The processes at step S625 and the following steps perform the total inspection of the vibration-proof controllability. The gain adjustment values A1 and A2 held in the CPU 1 at the timing at step S625 are the initial value A0 set at step S700 in Figure 10. The angle displacement adjustment value $\Delta\alpha$ and $\Delta\beta$ are the initial value 0 written at step S702 in Figure 10. At step S625, the data write instruction is issued. The values of 1/m of A1 and A2 calculated at step S622 are written in the gain adjustment values A1 and A2 in the CPU 1 and $\Delta\alpha$ and $\Delta\beta$ calculated at step S623 are written in the angle displacement adjustment values $\Delta\alpha$ and $\Delta\beta$ in the CPU 1. The process proceeds to step S626.

[0093]

At step S626, the shaking table 18 is vibrated. The vibration is sinusoidal and has a predetermined angular amplitude in the X axis direction. At step S627, the vibration-proof-control starting instruction is issued to the CPU 1. The CPU 1 executes the vibration-proof-control starting process according to the instruction at step S627 and based on step S709 in

Figure 10. The vibration-proof-control timer interrupt process illustrating in Figure 16 continues detecting the maximum values LRmax(X) and LRmax(Y) and the minimum values LRmin(X) and LRmin (Y) of the vibration-proof lens positions and the maximum values ΔLmax(X) and ΔLmax(Y) and the minimum values ΔLmin(X) and ΔLmin (Y) of the vibration-proof lens control errors. The execution is determined as the vibration-proof adjustment at step S1314 in Figure 16, so that the motor is driven to control the vibration-proof lens 13 as is not the case with the gain adjustment and the detection angle displacement adjustment.

[0094]

At step S628, the process waits for a predetermined period of time. At step S629, the vibration-proof control ending instruction is issued. The CPU 1 disables the vibration-proof-control timer interrupt process at step S712 in Figure 10 to end the vibration-proof control. At step S630, vibration is ended by the shaking table 18. The wait at step 628 is a time in which a period of vibration applied by the shaking table 18 is equal to or longer than one period at steps S627 to S629. The reason the wait is set to the above time is that a check is made as to whether controllability is good in all timings of one period of the sinusoidal wave, while the vibration proof lens 13 is sinusoidally controlled. The process proceeds to

step S631 in Figure 9 from step S630. At step S631, the maximum value LRmax(X) and the minimum value LRmin(X) of the X axis vibration-proof lens position and the maximum value ΔLmax(X) and the minimum value ΔLmin(X) of the X axis vibration-proof lens position error detected by the CPU 1 are read from the CPU 1 using the data read instruction. At step S632, an amplitude "g" in the X axis direction of the vibration-proof lens 13 actually controlled is calculated by the following equation (Expression 49):

(Expression 49) g = LRmax(X) - LRmin(X).

[0095]

At step S633, a determination is made as to whether the absolute value of a value in which the actual total amplitude "g" in the X axis direction of the vibration proof lens 13 obtained at step S632 is subtracted from the value of 1/m of the total amplitude L01 in the X axis direction of the vibration proof lens 13 desired to be obtained after gain adjustment is equal to or less than a predetermined value. If the absolute value is equal to or less than the predetermined value, the process proceeds to step S634. If not, the process proceeds to step S646, determines that the vibration-proof lens shifting mechanism is defective or adjustment is not sufficient and proceeds to step S647.

[0096]

Since the vibration-proof gain adjustment value A1 in the yaw direction obtained at step S622 is multiplied by 1/m at step S625, if the amplitude “g” of the vibration proof lens 13 actually obtained is equal to 1/m of L01, the gain adjustment can be considered accurate and the vibration-proof controllability can be considered good. However, if the gain adjustment is not accurately performed for some reason or if the total amplitude of the vibration proof lens 13 actually controlled is not theoretically obtained because the vibration-proof lens shifting mechanism is out of order, a defect can be checked based on determination at step S633.

[0097]

At step S634, a determination is made as to whether the absolute value of the maximum value ΔLmax(X) of a vibration-proof lens position error in the X axis direction is equal to or less than a predetermined value. If the absolute value is equal to or less than the predetermined value, the process proceeds to step S635. If not, the process proceeds to step S646, determines that the vibration-proof lens shifting mechanism is defective or adjustment is not sufficient and proceeds to step S647. At step S635, a determination is made as to whether the absolute value of the minimum value ΔLmin(X) of a vibration-proof lens position error in the X axis direction is equal to or

less than a predetermined value. If the absolute value is equal to or less than the predetermined value, the process proceeds to step S636. If not, the process proceeds to step S646, determines that the vibration-proof lens shifting mechanism is defective or adjustment is not sufficient and proceeds to step S647.

[0098]

The processes at steps S634 and S635 check controllability in the X axis direction of the vibration-proof lens 13. In the above vibration-proof-control timer interrupt process, the vibration-proof lens position error $\Delta L(X)$ being the difference between the vibration-proof lens target position LC(X) and the vibration-proof lens position LR(X) actually controlled is calculated and the maximum value $\Delta Lmax(X)$ and the minimum value $\Delta Lmin(X)$ of the vibration-proof lens position error are detected. At steps S634 and S635, if the absolute values of $\Delta Lmax(X)$ and $\Delta Lmin(X)$ are small, the controllability can be determined as good, or if the absolute values are great, the controllability can be determined as unacceptable.

[0099]

The processes at step S636 and the following steps check the vibration-proof controllability in the Y axis direction. At step S636, the shaking table 18 is vibrated. The vibration is sinusoidal and has a predetermined angular amplitude in the Y axis direction.

At step S637, the vibration-proof-control starting instruction is issued to the CPU 1. The CPU 1 executes the vibration-proof-control starting process according to the instruction at step S637 and based on step S709 in Figure 10. The vibration-proof-control timer interrupt process illustrating in Figure 16 continues detecting the maximum values LRmax(X) and LRmax(Y) and the minimum values LRmin(X) and LRmin (Y) of the vibration-proof lens positions and the maximum values ΔLmax(X) and ΔLmax(Y) and the minimum values ΔLmin(X) and ΔLmin (Y) of the vibration-proof lens control errors. The execution is determined as the vibration-proof adjustment at step S1314 in Figure 16, so that the motor is driven to control the vibration-proof lens 13.

[0100]

At step S638, the process waits for a predetermined period of time. At step S639, the vibration-proof control ending instruction is issued. The CPU 1 disables the vibration-proof-control timer interrupt process at step S712 in Figure 10 to end the vibration-proof control. At step S640, vibration is ended by the shaking table 18. The wait at step 638 is a time in which a period of vibration applied by the shaking table 18 is equal to or longer than one period at steps S637 to S639. The reason to do so is the same as in the wait at step S628. At step S641, the maximum

value LRmax(Y) and the minimum value LRmin(Y) of the Y axis vibration-proof lens position and the maximum value ΔLmax(Y) and the minimum value ΔLmin(Y) of the Y axis vibration-proof lens position error detected by the CPU 1 are read from the CPU 1 using the data read instruction. At step S642, an amplitude "h" in the Y axis direction of the vibration-proof lens 13 actually controlled is calculated by the following equation (Expression 50):

(Expression 50) h = LRmax(Y) - LRmin(Y).

[0101]

At step S643, a determination is made as to whether the absolute value of a value in which the actual total amplitude "h" in the Y axis direction of the vibration proof lens 13 obtained at step S642 is subtracted from the value of 1/m of the total amplitude L02 in the Y axis direction of the vibration proof lens 13 desired to be obtained after gain adjustment is equal to or less than a predetermined value. If the absolute value is equal to or less than the predetermined value, the process proceeds to step S644. If not, the process proceeds to step S646, determines that the vibration-proof lens shifting mechanism is defective or adjustment is not sufficient and proceeds to step S647. The reason the above determination is made at step S643 is the same as that at step S633.

[0102]

At step S644, a determination is made as to whether the absolute value of the maximum value ΔLmax(Y) of a vibration-proof lens position error in the Y axis direction is equal to or less than a predetermined value. If the absolute value is equal to or less than the predetermined value, the process proceeds to step S645. If not, the process proceeds to step S646, determines that the vibration-proof lens shifting mechanism is defective or adjustment is not sufficient and proceeds to step S647. At step S645, a determination is made as to whether the absolute value of the minimum value ΔLmin(Y) of a vibration-proof lens position error in the Y axis direction is equal to or less than a predetermined value. If the absolute value is equal to or less than the predetermined value, the process proceeds to step S647. If not, the process proceeds to step S646, determines that the vibration-proof lens shifting mechanism is defective or adjustment is not sufficient and proceeds to step S647.

[0103]

The processes at steps S644 and S645 check controllability in the Y axis direction of the vibration-proof lens 13. In the above the vibration-proof-control timer interrupt process, the vibration-proof lens position error ΔL(Y) being a difference between the vibration-proof lens target position LC(Y) and the vibration-proof lens position LR(Y) actually

controlled is calculated and the maximum value $\Delta Lmax(Y)$ and the minimum value $\Delta Lmin(Y)$ of the vibration-proof lens position error are detected. At steps S644 and S645, if the absolute values of $\Delta Lmax(Y)$ and $\Delta Lmin(Y)$ are small, the controllability can be determined as good, or if the absolute values are great, the controllability can be determined as unacceptable.

[0104]

At step S647, the vibration-proof lens resetting instruction is issued to the CPU 1. The CPU 1 drives the vibration proof lens 13 to a predetermined position based on step S704 in Figure 10. At step S648, the communication mode release instruction is issued to the CPU 1 to release the camera from the communication mode. At step S649, the communication-tool adjustment process is ended.

[0105]

The reason the gain adjustment values A1 and A2 are set to 1/m respectively at step S625 is due to the following. The outputs of the yaw and the pitch angular velocity detecting circuit 8 and 9 are typically increased at the time of the gain adjustment and the angle displacement adjustment to gain the dynamic range, thereby improving an accuracy in adjustment. Therefore, the vibration angle of the shaking table 18 is also increased. In this case, when the above vibration-proof controllability is checked

with the vibration angle remained unchanged, the vibration proof lens 13 needs controlling beyond the driving capacity of vibration-proof lens shifting mechanism or the shift range of the vibration proof lens 13 can be exceeded.

[0106]

The angle range or the angle velocity of hand shake of a user who uses an ordinary camera is smaller than an angle at which the gain adjustment and angle displacement adjustment are performed. Accordingly, the vibration angle of the shaking table 18 may be decreased only at the time of checking the vibration-proof controllability to meet the above. However, it is not easy to mechanically set the vibration angle of the shaking table 18 to two steps. For this reason, the value of “m” is set so as to cover the angle range or the angle velocity range generated when a user uses an ordinary camera, checking a realistic vibration-proof controllability. The value of “m” is varied to check such a realistic vibration-proof controllability, enabling a more accurate check. On the other hand, it is not easy to mechanically set the vibration angle of the shaking table 18 to a plurality of steps.

[0107]

A process in the case where the camera is used by a user is described below. Figure 20 is a flow chart illustrating one embodiment of the half-depression

process for the camera according to the present invention. The process illustrated in Figure 20 is performed when the half-depression SW 16 is turned on. At step S1700, the process starts. At step S1701, the gain adjustment values A1 and A2 are at read from the E2PROM. At step S1702, the angle displacement adjustment values $\Delta\alpha$ and $\Delta\beta$ are read from the E2PROM. At step S1703, a determination is made as to whether the full-depression SW 17 is turned on. If the SW 17 is turned on, the process proceeds to step S1706. If the SW 17 is turned off, the process proceeds to step S1704 to determine whether the half-depression SW 16 is turned on. If the SW 16 is turned on, the process returns to step S1703. If the SW 16 is turned off, the process proceeds to step S1705 to end the process.

[0108]

At step S1706, the foregoing vibration-proof lens centering process (Figure 12) is performed to drive the vibration proof lens 13 to the center positions in the X and the Y axis direction. At step S1707, the vibration-proof-control starting process (Figure 13) is performed. The vibration-proof-control timer interrupt process (Figure 16) is permitted to start the vibration-proof control. At step S1708, a shutter is opened and closed to perform an exposure process. After the exposure process is ended, the vibration-proof-control timer interrupt is disabled at step S1709

to end the vibration-proof-control. In addition, the motors 4 and 5 are rendered into a short brake for a predetermined period of time to end the vibration proof lens 13. At step S1710, the vibration-proof lens resetting process (Figure 11) drives the vibration proof lens 13 to a reset position. The process proceeds to step S1711 to end the present half-depression process.

[0109]

In the vibration-proof-control timer interrupt between the start of the vibration-proof-control at step S1707 and the end of the vibration-proof-control at step S1709 including the exposure at step S1708, the vibration-proof-control is performed by the output in which the gain adjustment values A1 and A2 and the angle displacement adjustment values $\Delta\alpha$ and $\Delta\beta$ are read from the E2PROM at steps S1701 and S1702, the dispersion in the gains is corrected at step S1306 and the angle displacement is corrected at step S1307. Thereby, an accurate vibration-proof control is performed.

[0110]

One embodiment of the present invention has been described above. The present invention can be implemented in various forms without limiting to the above embodiment and deviating from the gist of the present invention. For example, although, in the above

embodiment, the amount of angle displacement is electrically detected to write the adjustment value thereof into the E2PROM of the camera to electrically correct the angle displacement, the amount of angle displacement is detected by this method and the angle displacement may be adjusted by mechanically adjusting an angular velocity sensor or an angular velocity detecting circuit. Although, in the above description, the speed of the motors 4 and 5 is controlled by the PWM control method, the control method of the motors 4 and 5 are not limited to the above. In the above description of the present embodiment, as a method of varying the optical axis of a photographing optical system, there is used a method of shifting a part (the vibration proof lens 13) of the photographing optical system, however, aside from the above, a vari-angle prism may be used or other actuators such as a voice coil may be used instead of the motor.

[0111]

In the embodiment of the present embodiment, although the communication-tool side inspects and adjusts the shake correction function of the camera, in addition to the above, for example, the inspection and the adjustment function are provided on the CPU 1 of the camera to enable the camera to be self diagnosed.

[0112]

[Advantages of the Invention]

According to the present invention, since a first and second adjustment values of angle displacements between a first and second directions in which the optical axis of a photographing optical system varies and the directions of the angle velocities detected by a first and second angular velocity detecting units are stored to correct errors of outputs of the first and second angular velocity detecting units based on the first and second adjustment values of angle displacements, a more accurate shake correction can be performed independently of the influence of error in attachment of the first and second angular velocity detecting units at the time of assembly of the camera. In the case where the angle displacement is adjusted based on the integral value or the accumulated value of outputs of the first and second angular velocity detecting circuits, accuracy in adjustment can be prevented from lowering due to variation in the frequency of a sinusoidal vibration applied at the time of adjusting the angle displacement or an unwanted high-frequency noise superposed on the sinusoidal vibration, enabling more accurate adjustment of the angle displacement.

[Brief Description of the Drawings]

[Figure 1]

Figure 1 is a schematic diagram illustrating the configuration of portions of a camera, a communication

tool and a shaking table.

[Figure 2]

Figure 2 is a schematic diagram illustrating dispersion in the gains of the yaw and the pitch angular velocity detecting circuit 8 and 9.

[Figure 3]

Figure 3 is a chart describing a angle displacement.

[Figure 4]

Figure 4 is a chart illustrating how the gain and the angle displacement are adjusted according to the present invention.

[Figure 5]

Figure 5 is a chart illustrating how the gain and the angle displacement are adjusted according to the present invention.

[Figure 6]

Figure 6 is a chart describing the centering control in the X axis direction of the vibration-proof lens 13.

[Figure 7]

Figure 7 is a flow chart illustrating one embodiment of a communication adjustment process performed by the communication tool 15.

[Figure 8]

Figure 8 is a flow chart following Figure 7.

[Figure 9]

Figure 9 is a flow chart following Figure 8.

[Figure 10]

Figure 10 is a flow chart illustrating one embodiment of a communication-mode process performed by the CPU 1 of the camera.

[Figure 11]

Figure 11 is a flow chart illustrating one embodiment of a vibration-proof lens resetting process at step S704 in Figure 10.

[Figure 12]

Figure 12 is a flow chart illustrating one embodiment of the vibration-proof lens centering process at step S706 in Figure 10.

[Figure 13]

Figure 13 is a flow chart illustrating one embodiment of the vibration-proof-control starting process at step S709 in Figure 10.

[Figure 14]

Figure 14 is a flow chart illustrating one embodiment of the vibration-proof lens resetting timer interrupt process.

[Figure 15]

Figure 15 is a flow chart illustrating one embodiment of the vibration-proof lens centering timer interrupt process.

[Figure 16]

Figure 16 is a flow chart illustrating one

embodiment of the vibration-proof-control timer interrupt process.

[Figure 17]

Figure 17 is a flow chart illustrating one embodiment of a process for detecting the maximum and the minimum values of the vibration-proof lens positions.

[Figure 18]

Figure 18 is a flow chart illustrating one embodiment of a process for detecting the maximum and the minimum values of the vibration-proof lens target position.

[Figure 19]

Figure 19 is a flow chart illustrating one embodiment of a process for detecting the maximum and the minimum values of the vibration-proof lens position error.

[Figure 20]

Figure 20 is a flow chart illustrating one embodiment of the half-depression process for the camera according to the present invention.

[Description of Symbols]

1 CPU

2, 3 X and Y axis motor driving circuits

4, 5 X and Y axis motors

6, 7 X and Y axis lens position detecting circuits

8, 9 Yaw and pitch angular velocity detecting circuits

10 E2PROM

11, 12, 13, 14 Photographic lens (13, Vibration proof lens)

15 Communication tool

16 Half depression SW

17 Full-depression SW

18 Shaking table

Figure 1

#1 CAMERA SIDE

#2 COMMUNICATION TOOL SIDE

#3 SHAKING TABLE SIDE

2 X AXIS MOTOR DRIVING CIRCUIT

3 Y AXIS MOTOR DRIVING CIRCUIT

6 X AXIS LENS POSITION DETECTING CIRCUIT

7 Y AXIS LENS POSITION DETECTING CIRCUIT

8 YAW ANGULAR VELOCITY DETECTING CIRCUIT

9 PITCH ANGULAR VELOCITY DETECTING CIRCUIT

15 COMMUNICATION TOOL

16 HALF DEPRESSION SW

17 FULL DEPRESSION SW

18 SHAKING TABLE

Figure 2

#1 DIRECTION

#2 ANGULAR VELOCITY DETECTING CIRCUIT

#3 ANGULAR VELOCITY SENSOR

Figure 3

#1 AXIS DRIVE DIRECTION

#2 SENSOR DETECTION DIRECTION

#3 APPLIED ANGULAR VELOCITY DIRECTION

Figure 4

#1 AT THE TIME OF APPLYING VIBRATION IN X AXIS

DIRECTION

Figure 5

#1 AT THE TIME OF APPLYING VIBRATION IN X AXIS DIRECTION

Figure 7

S600 START COMMUNICATION TOOL ADJUSTMENT PROCESS

S601 PLACE CAMERA INTO COMMUNICATION MODE

S602 ISSUE VIBRATION-PROOF LENS RESETTING INSTRUCTION

S603 ISSUE VIBRATION-PROOF LENS CENTERING INSTRUCTION

S604 READ VRmax(X) AND VRmax(Y) AND EACH CENTERING ABNORMALITY DATA FROM CAMERA

S605 IS VRmax(X) EQUAL TO OR GREATER THAN PREDETERMINED VALUE?

S606 IS VRmax(Y) EQUAL TO OR GREATER THAN PREDETERMINED VALUE?

S607 IS CENTERING ABNORMAL?

S608 START APPLYING VIBRATION IN X AXIS DIRECTION

S609 ISSUE VIBRATION-PROOF ADJUSTMENT STARTING INSTRUCTION

S610 WAIT FOR PREDETERMINED PERIOD OF TIME

S611 ISSUE VIBRATION-PROOF ADJUSTMENT ENDING INSTRUCTION

S612 END APPLICATION OF VIBRATION IN X AXIS

DIRECTION

S613 READ LCmax(X), LCmin(X) AND SIGN OF LC(Y) AT THE TIME OF DETECTING LCmax(X) FROM CAMERA AND READ LCmax(Y), LCmin(Y) AND SIGN OF LC(X) AT THE TIME OF DETECTING LCmax(Y) FROM CAMERA

#1 POSITIVE IN SIGN OF LC(Y) AT THE TIME OF DETECTING LCmax(X)

NEGATIVE IN SIGN OF LC(Y) AT THE TIME OF DETECTING LCmax(X)

Figure 8

S615 START APPLICATION OF VIBRATION IN Y AXIS DIRECTION

S616 ISSUE VIBRATION-PROOF ADJUSTMENT STARTING INSTRUCTION

S617 WAIT FOR PREDETERMINED PERIOD OF TIME

S618 ISSUE VIBRATION-PROOF ADJUSTMENT ENDING INSTRUCTION

S619 END APPLICATION OF VIBRATION IN Y AXIS DIRECTION

S620 READ LCmax(X), LCmin(X) AND SIGN OF LC(Y) AT THE TIME OF DETECTING LCmax(X) FROM CAMERA AND READ LCmax(Y), LCmin(Y) AND SIGN OF LC(X) AT THE TIME OF DETECTING LCmax(Y) FROM CAMERA

#1 POSITIVE IN SIGN OF LC(X) AT THE TIME OF DETECTING LCmax(Y)

NEGATIVE IN SIGN OF LC(X) AT THE TIME OF

DETECTING LCmax(Y)

#2 CALCULATE GAIN ADJUSTMENT VALUE OF ANGULAR VELOCITY DETECTING CIRCUIT

#3 CALCULATE DETECTION ANGLE DISPLACEMENT CORRECTION AMOUNT OF ANGULAR VELOCITY DETECTING CIRCUIT

S624 WRITE A1, A2, $\Delta\alpha$ AND $\Delta\beta$ IN E2PROM OF CAMERA

S625 WRITE A1/m, A2/m, $\Delta\alpha$ AND $\Delta\beta$ IN PREDETERMINED DATA OF CPU 1

S626 START APPLYING VIBRATION IN X AXIS DIRECTION

S627 ISSUE VIBRATION-PROOF CONTROL STARTING INSTRUCTION

S628 WAIT FOR PREDETERMINED PERIOD OF TIME

S629 ISSUE VIBRATION-PROOF CONTROL ENDING INSTRUCTION

S630 END APPLICATION OF VIBRATION IN X AXIS DIRECTION

Figure 9

S631 READ LRmax(X), LRmin(X), ΔLmax(X) and ΔLmin(X) FROM CAMERA

#1 PREDETERMINED VALUE

S636 START APPLYING VIBRATION IN Y AXIS DIRECTION

S637 ISSUE VIBRATION-PROOF CONTROL STARTING INSTRUCTION

S638 WAIT FOR PREDETERMINED PERIOD OF TIME

S639 ISSUE VIBRATION-PROOF CONTROL ENDING INSTRUCTION

S640 END APPLICATION OF VIBRATION IN Y AXIS DIRECTION

S641 READ LRmax(Y), LRmin(Y), ΔLmax(Y) AND ΔLmin(Y) FROM CAMERA

S646 DEFECTIVE MECHANISM OR INSUFFICIENT ADJUSTMENT

S647 ISSUE VIBRATION-PROOF LENS RESETTING INSTRUCTION

S648 RELEASE CAMERA FROM COMMUNICATION MODE

S649 END PROCESS

Figure 10

S700 START COMMUNICATION MODE OF CAMERA

#1 SET INITIAL VALUE OF ANGULAR VELOCITY GAIN ADJUSTMENT VALUES

#2 CLEAR ANGULAR VELOCITY DETECTING ANGLE DISPLACEMENT CORRECTION VALUES

S703 IS VIBRATION-PROOF LENS RESETTING INSTRUCTION ISSUED?

S704 VIBRATION-PROOF LENS RESETTING PROCESS

S705 IS VIBRATION-PROOF LENS CENTERING INSTRUCTION ISSUED?

S706 VIBRATION-PROOF LENS CENTERING PROCESS

S707 IS VIBRATION-PROOF ADJUSTMENT STARTING INSTRUCTION ISSUED?

S708 IS VIBRATION-PROOF CONTROL STARTING INSTRUCTION ISSUED?

S709 VIBRATION-PROOF CONTROL STARTING PROCESS

S710 IS VIBRATION-PROOF ADJUSTMENT ENDING INSTRUCTION ISSUED?

S711 IS VIBRATION-PROOF CONTROL ENDING INSTRUCTION ISSUED?

S712 DISABLE VIBRATION-PROOF-CONTROL TIMER INTERRUPT PROCESS AND END VIBRATION-PROOF CONTROL

S713 IS DATA READ INSTRUCTION ISSUED?

S714 TRANSFER SPECIFIED DATA TO COMMUNICATION TOOL

S715 IS DATA WRITE INSTRUCTION ISSUED?

S716 WRITE DATA TRANSFERRED BY COMMUNICATION TOOL IN PREDETERMINED DATA

S717 IS E2PROM WRITE INSTRUCTION ISSUED

S718 WRITE DATA TRANSFERRED BY COMMUNICATION TOOL IN E2PROM

S719 IS COMMUNICATION MODE RELEASE INSTRUCTION ISSUED?

S720 END PROCESS

Figure 11

S800 START VIBRATION-PROOF LENS RESETTING PROCESS

S801 START VIBRATION-PROOF LENS RESETTING (PERMIT VIBRATION-PROOF LENS RESETTING TIMER INTERRUPT)

S802 WAIT FOR PREDETERMINED PERIOD OF TIME

S803 IS X AXIS VIBRATION-PROOF LENS RESETTING ENDED?

IS Vrmax(X) EQUAL TO OR LESS THAN PREDETERMINED VALUE?

S804 IS Y AXIS VIBRATION-PROOF LENS RESETTING ENDED?

IS Vrmax(Y) EQUAL TO OR LESS THAN PREDETERMINED VALUE?

S805 RETURN

Figure 12

S900 START VIBRATION-PROOF LENS CENTERING PROCESS

S901 CLEAR X AND Y AXIS VIBRATION-PROOF LENS STOP FLG, VIBRATION-PROOF LENS CENTERING TIME-OUT ABNORMALITY FLG, X AND Y AXIS VIBRATION-PROOF LENS MOTION ABNORMALITY FLG AND X AND Y AXIS VIBRATION-PROOF LENS POSITION DETECTION ABNORMALITY FLG

S902 SET VIBRATION-PROOF LENS CENTERING PROCESS INTERRUPT TIME-OUT TIME

S903 START VIBRATION-PROOF LENS CENTERING (PERMIT THE VIBRATION-PROOF LENS CENTERING TIMER INTERRUPT)

S904 WAIT FOR PREDETERMINED PERIOD OF TIME

#1 CLEAR MAXIMUM AND MINIMUM VELOCITIES OF VIBRATION-PROOF LENS

S906 IS VIBRATION-PROOF LENS CENTERING PROCESS INTERRUPT TIMER TIMED OUT?

S907 SET VIBRATION-PROOF LENS CENTERING TIME-OUT ABNORMALITY FLG

#2 PREDETERMINED VALUE

S909 SET X AXIS VIBRATION-PROOF LENS MOTION ABNORMALITY FLG

S911 SET Y AXIS VIBRATION-PROOF LENS MOTION ABNORMALITY FLG

S913 SET X AXIS VIBRATION-PROOF LENS POSITION DETECTION ABNORMALITY FLG

S915 SET Y AXIS VIBRATION-PROOF LENS POSITION DETECTION ABNORMALITY FLG

S916 IS OPERATION OF VIBRATION-PROOF LENS IN X AXIS DIRECTION STOPPED?

S917 IS OPERATION OF VIBRATION-PROOF LENS IN Y AXIS DIRECTION IS STOPPED?

S918 DISABLE VIBRATION-PROOF LENS CENTERING TIMER INTERRUPT PROCESS TO RENDER MOTORS INTO SHORT-BRAKE STATE TO STOP VIBRATION-PROOF LENS

S919 RETURN

Figure 13

S1000 START VIBRATION-PROOF CONTROL PROCESS

#1 SET INITIAL VALUE OF VIBRATION-PROOF LENS TARGET POSITION

#2 CURRENT VIBRATION-PROOF LENS POSITION OF X AXIS

#3 CURRENT VIBRATION-PROOF LENS POSITION OF Y AXIS

#4 SET INITIAL VALUE OF MAXIMUM AND MINIMUM VALUES VIBRATION-PROOF LENS TARGET POSITION

#5 SET INITIAL VALUE OF MAXIMUM AND MINIMUM VALUES VIBRATION-PROOF LENS POSITION

#6 CLEAR VIBRATION-PROOF LENS POSITION ERROR ΔL

S1005 START VIBRATION-PROOF CONTROL (PERMIT THE VIBRATION-PROOF-CONTROL TIMER INTERRUPT)

S1006 RETURN

Figure 14

S1100 START VIBRATION-PROOF LENS RESETTING TIMER INTERRUPT PROCESS (X AXIS)

#1 RENEW VIBRATION-PROOF LENS POSITION

#2 DETECT VIBRATION-PROOF LENS POSITION

#3 DETECTED VALUE (X AXIS)

#4 CALCULATE VIBRATION-PROOF LENS VELOCITY

S1104 DRIVE MOTOR AT PREDETERMINED DRIVE DUTY

S1105 END INTERRUPT

Figure 15

S1200 START VIBRATION-PROOF LENS CENTERING TIMER INTERRUPT PROCESS (X AXIS)

#1 RENEW VIBRATION-PROOF LENS POSITION

#2 DETECT VIBRATION-PROOF LENS POSITION

#3 DETECTED VALUE (X AXIS)

#4 CALCULATE VIBRATION-PROOF LENS VELOCITY

S1209 SET X AXIS VIBRATION-PROOF LENS STOP FLG

S1210 RENDER MOTOR INTO SHORT-BRAKE STATE

#5 CALCULATE TARGET VELOCITY OF VIBRATION-PROOF LENS

S1212 CALCULATE DRIVE DUTY

S1213 DRIVE MOTOR AT SET DRIVE DUTY

S1214 END INTERRUPT

Figure 16

S1300 START VIBRATION-PROOF-CONTROL TIMER INTERRUPT PROCESS (X AXIS)

#1 RENEW VIBRATION-PROOF LENS POSITION

#2 DETECT VIBRATION-PROOF LENS POSITION

#3 DETECTED VALUE (X AXIS)

S1303 DETECTION PROCESS OF MAXIMUM AND MINIMUM VALUES OF VIBRATION-PROOF LENS POSITION

#4 CALCULATE VIBRATION-PROOF LENS VELOCITY

#5 A/D CONVERT OUTPUT OF YAW ANGULAR VELOCITY DETECTING CIRCUIT

#6 A/D CONVERTED VALUE

#7 CALCULATE GAIN ADJUSTMENT

#8 CALCULATE ANGLE DISPLACEMENT CORRECTION

#9 CALCULATE TARGET VELOCITY OF VIBRATION-PROOF LENS

#10 CALCULATE TARGET POSITION OF VIBRATION-PROOF LENS

S1310 DETECTION PROCESS OF MAXIMUM AND MINIMUM VALUES OF VIBRATION-PROOF LENS TARGET POSITION

#11 CALCULATE VIBRATION-PROOF LENS POSITION ERROR

S1312 DETECTION PROCESS OF MAXIMUM AND MINIMUM VALUES OF VIBRATION-PROOF LENS POSITION ERROR

S1313 CALCULATE VIBRATION-PROOF CONTROL DRIVE DUTY

S1314 IS VIBRATION-PROOF ADJUSTMENT PERFORMED?

S1315 DRIVE MOTOR AT SET DRIVE DUTY

S1316 END INTERRUPT

Figure 17

S1400 START DETECTION PROCESS OF MAXIMUM AND MINIMUM VALUES OF VIBRATION-PROOF LENS POSITION (X AXIS)

S1406 RETURN

Figure 18

S1500 START DETECTION PROCESS OF MAXIMUM AND MINIMUM VALUES OF VIBRATION-PROOF LENS TARGET POSITION (X AXIS)

S1503 HOLD SIGNS OF LC(Y)

S1506 RETURN

Figure 19

S1600 START DETECTION PROCESS OF MAXIMUM AND MINIMUM VALUES OF VIBRATION-PROOF LENS POSITION ERROR (X AXIS)

S1605 RETURN

Figure 20

S1700 START HALF DEPRESSION PROCESS

#1 READ ANGULAR VELOCITY GAIN ADJUSTMENT VALUE

#2 READ DETECTION ANGLE DISPLACEMENT CORRECTION VALUE

S1703 IS FULL-DEPRESSION SW TURNED ON?

S1704 IS HALF-DEPRESSION SW TURNED ON?

S1705 END PROCESS

S1706 VIBRATION-PROOF LENS CENTERING PROCESS

S1707 VIBRATION-PROOF-CONTROL STARTING PROCESS

S1708 EXPOSE

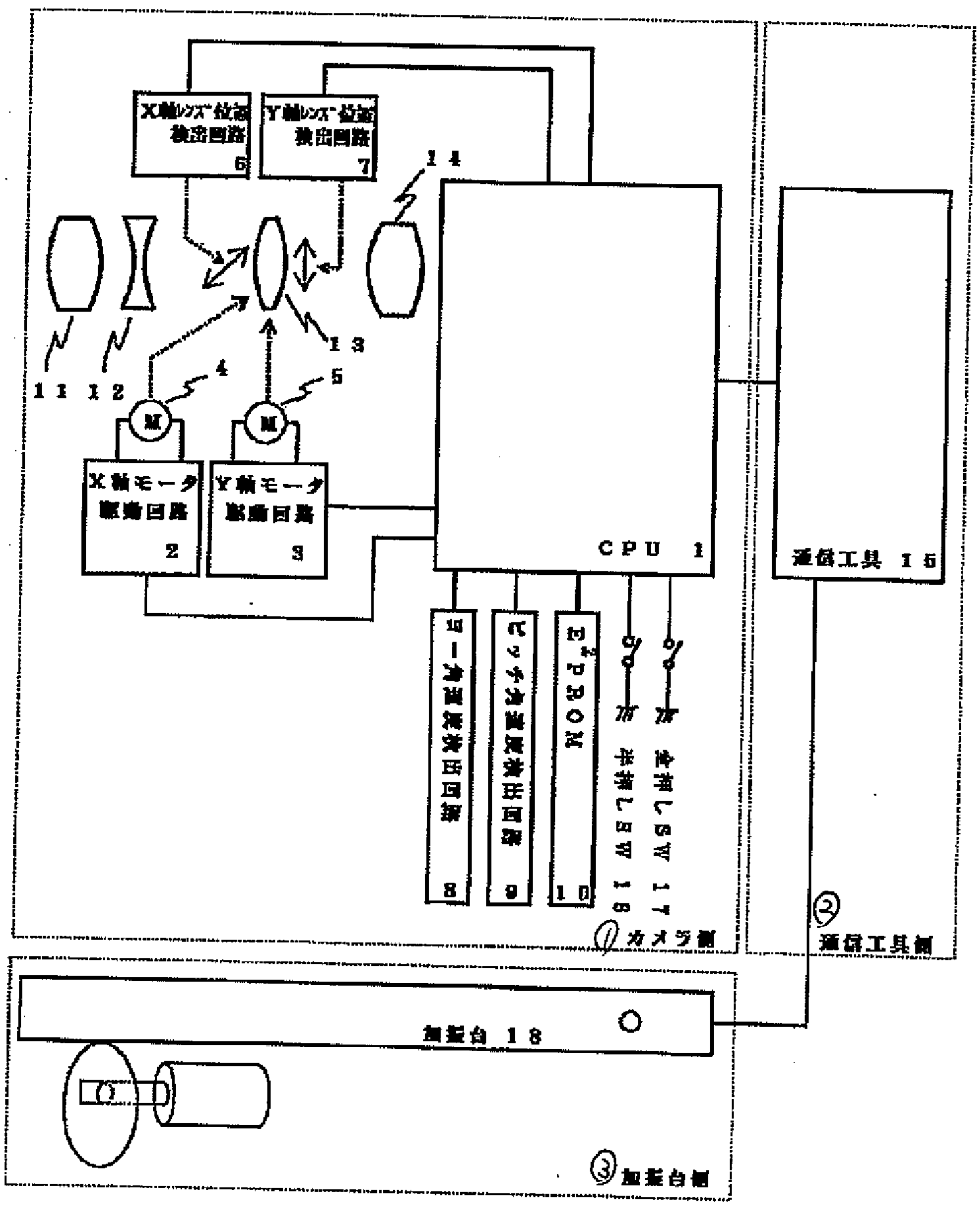
S1709 END VIBRATION-PROOF CONTROL AND RENDER MOTOR INTO SHORT BRAKE FOR PREDETERMINED PERIOD OF TIME TO STOP VIBRATION-PROOF LENS

S1710 VIBRATION-PROOF LENS RESETTING PROCESS

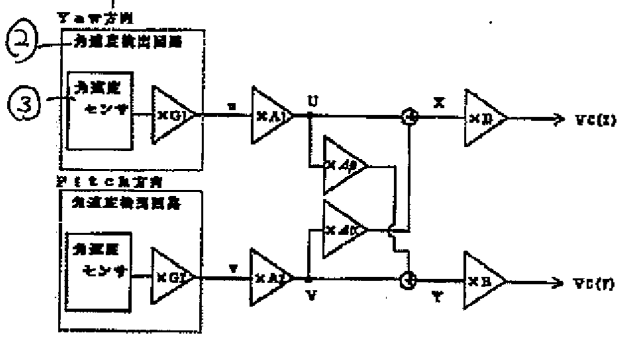
S1711 END PROCESS

16　半押しSW
17　全押しSW
＊18　加振台
＊

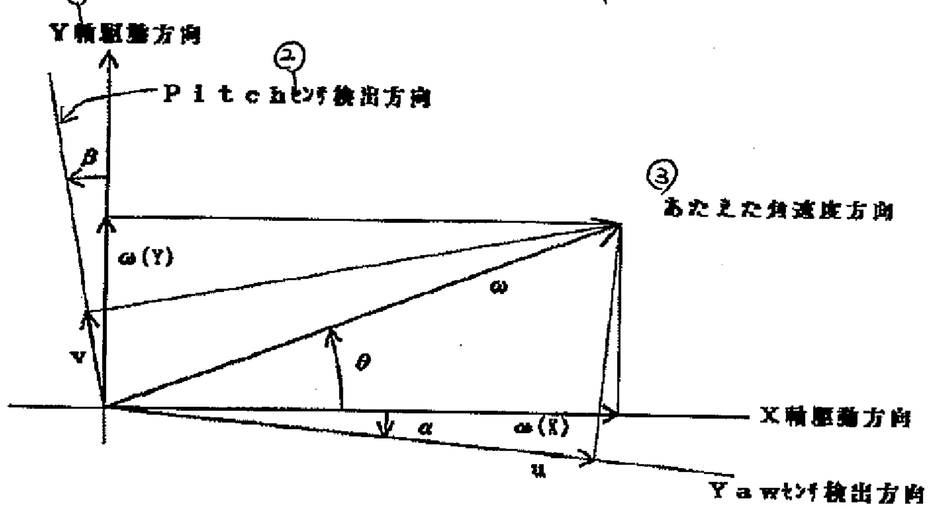
【図1】 FIG. 1



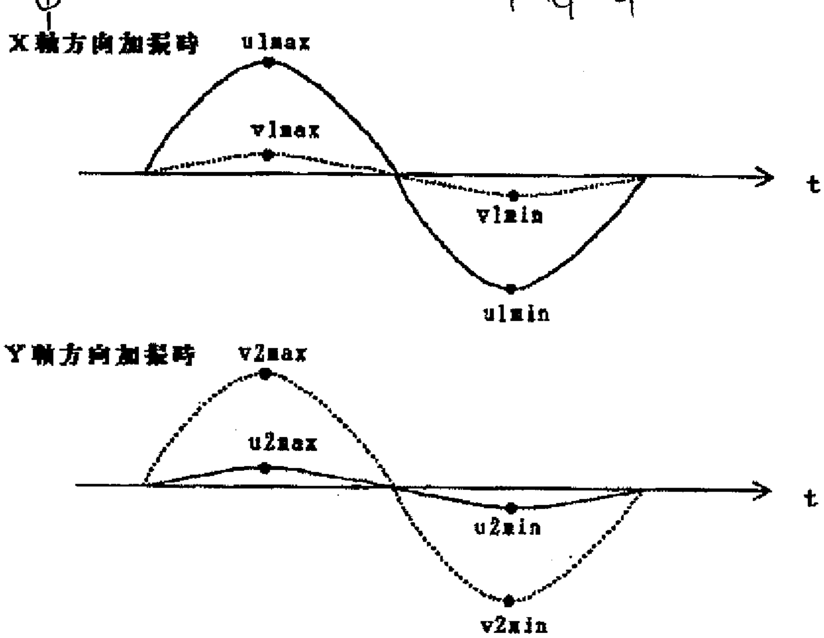
【図2】 FIG. 2



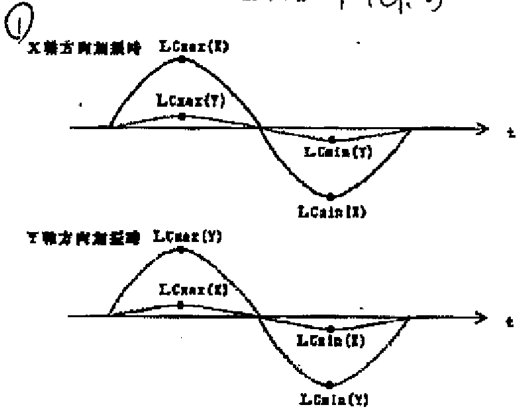
【図3】 FIG. 3



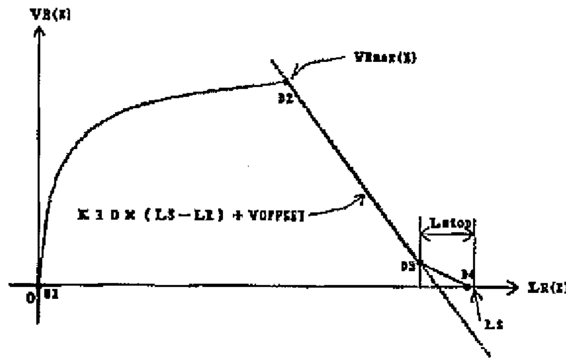
【図4】 FIG. 4



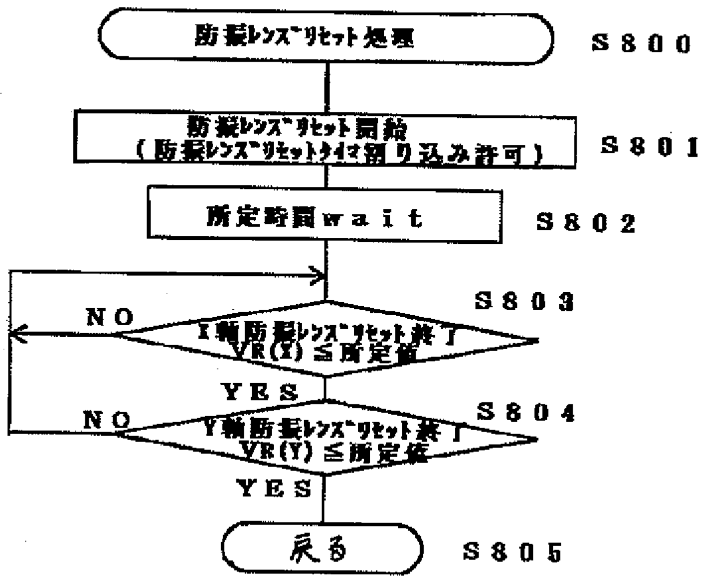
【図5】 FIG. 5



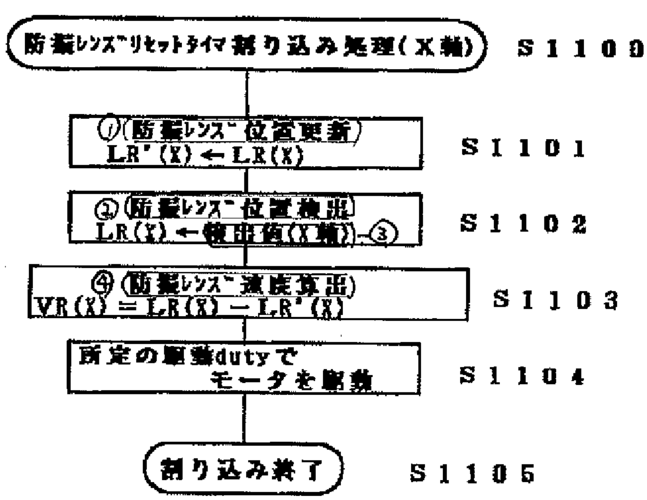
【図6】 FIG. 6



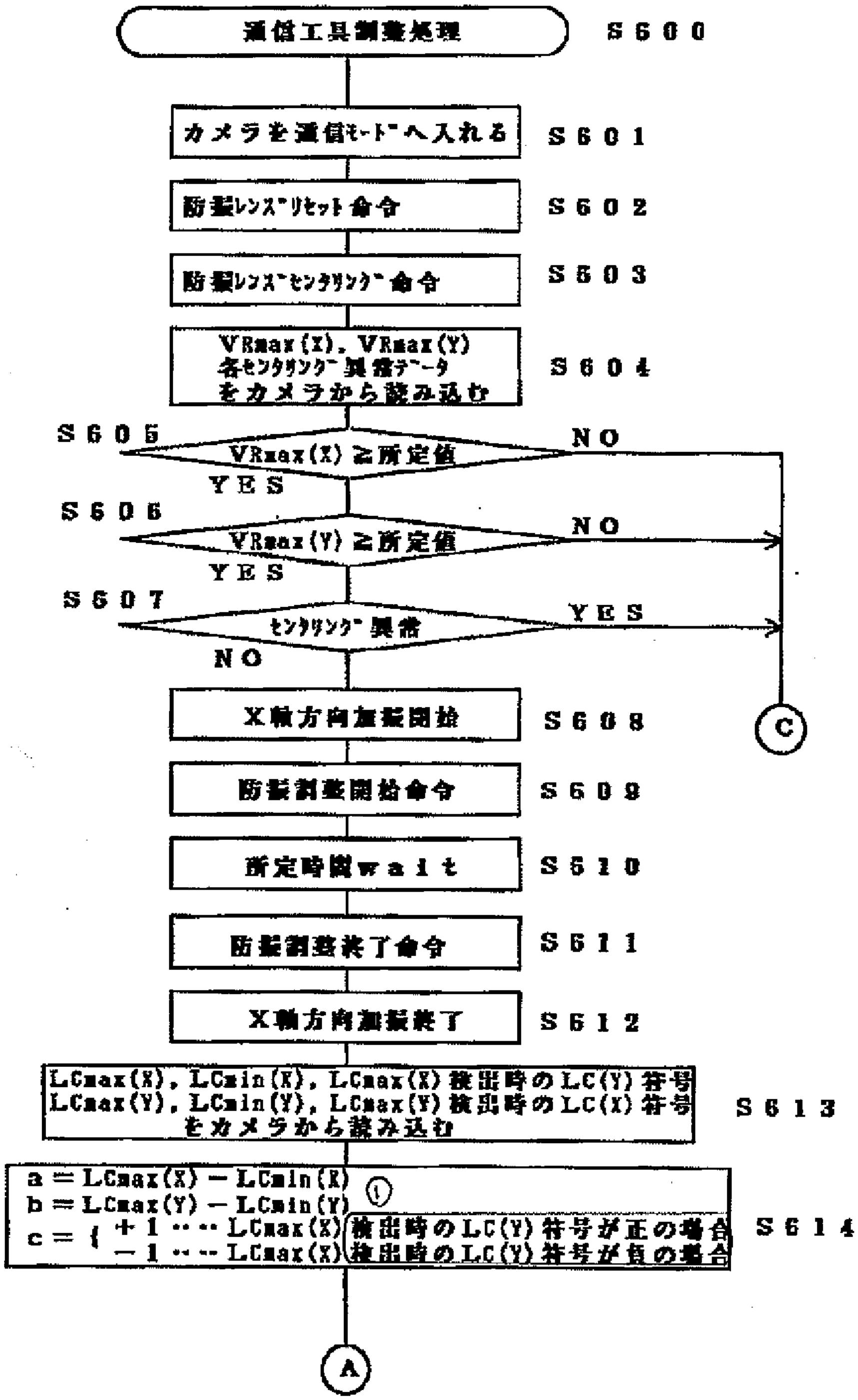
【図11】 FIG. 11



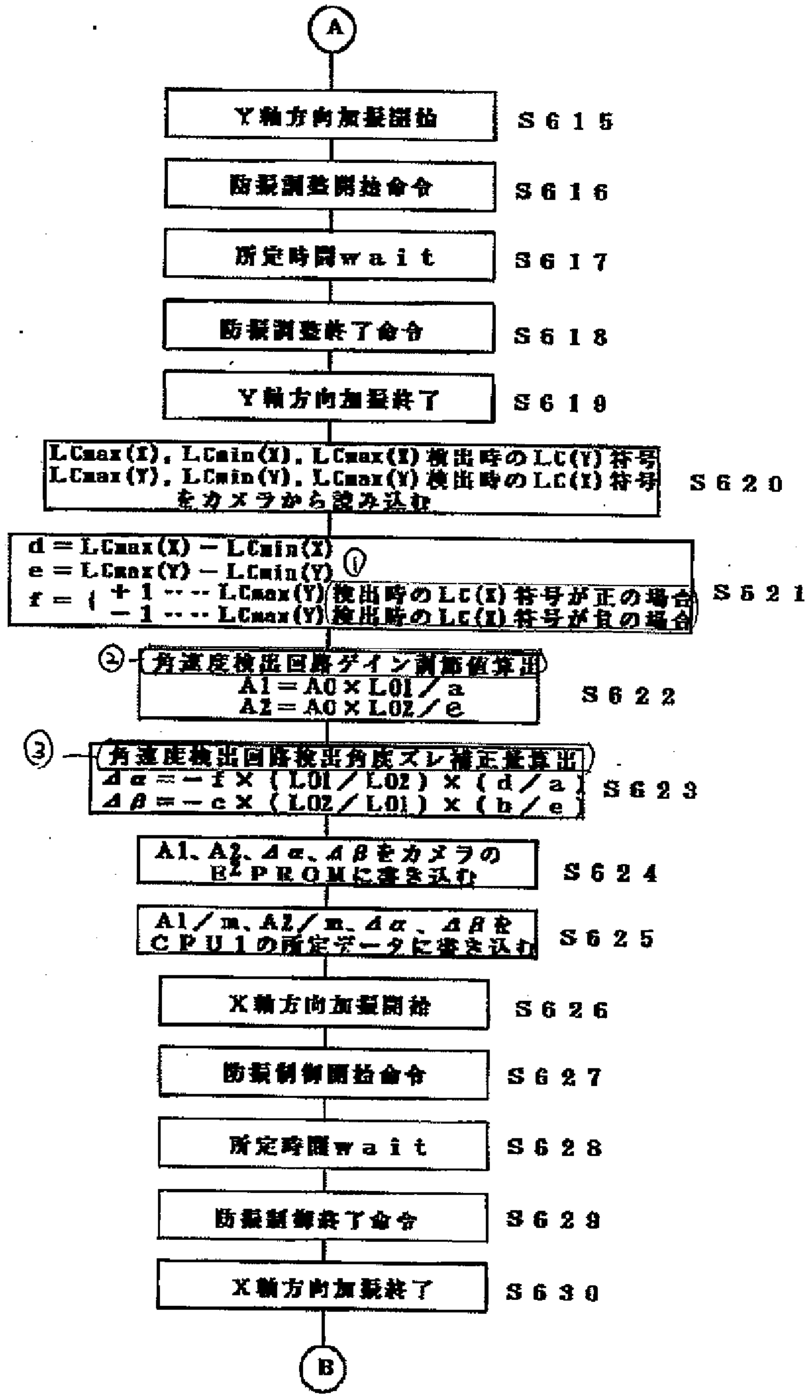
【図14】 FIG. 14



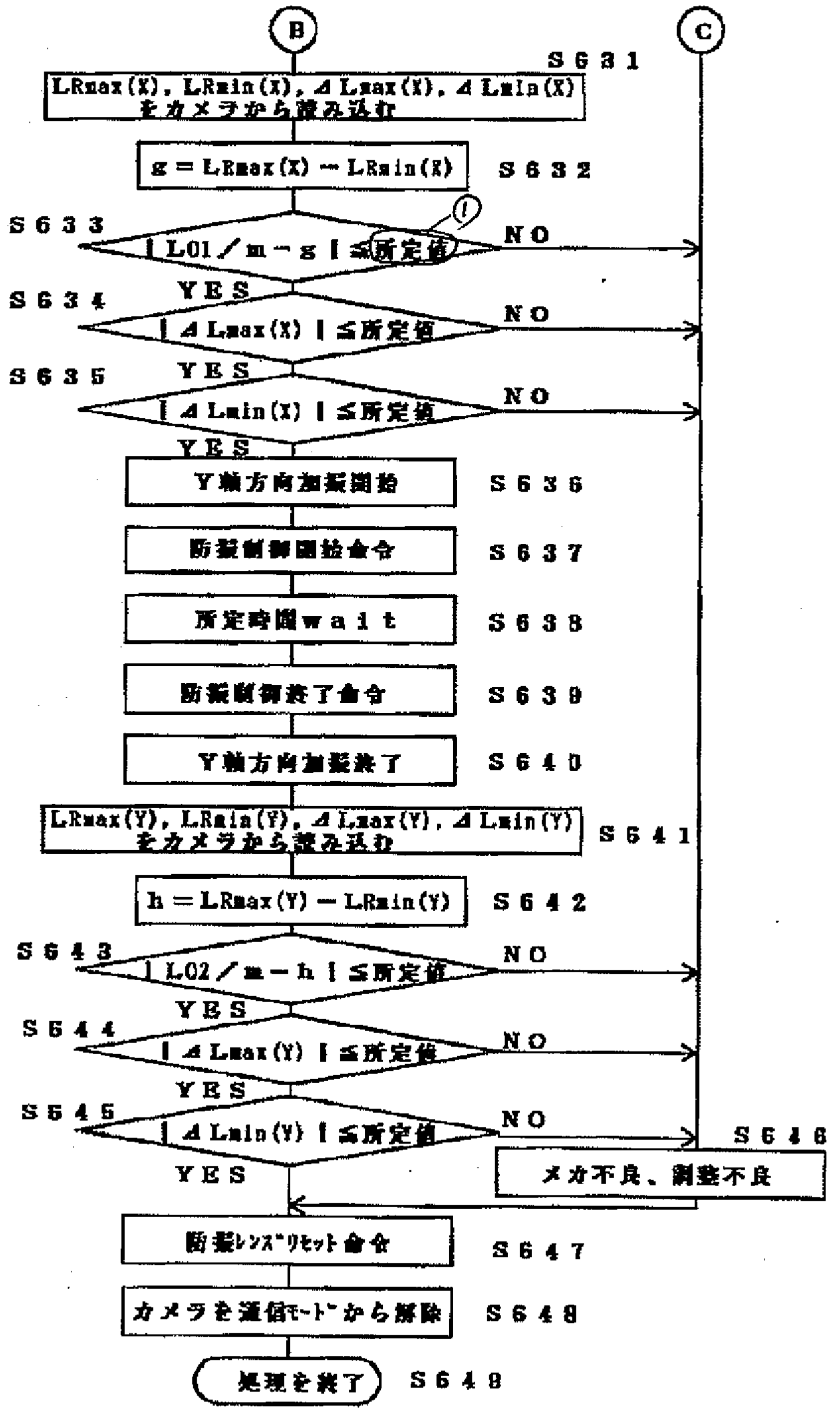
【図7】 FIG. 7


通信工具調整処理
S600
カメラを通信モードへ入れる
S601
防振レンズリセット命令
S602
防振レンズセンタリング命令
S603
VRmax(X), VRmax(Y)
各センタリング異常データ
をカメラから読み込む
S604
S605
VRmax(X) ≧所定値
NO
YES
S606
VRmax(Y) ≧所定値
NO
YES
S607
センタリング異常
YES
NO
X軸方向加振開始
S608
C
防振調整開始命令
S609
所定時間wait
S610
防振調整終了命令
S611
X軸方向加振終了
S612
LCmax(X), LCmin(X), LCmax(X)検出時のLC(Y)符号
LCmax(Y), LCmin(Y), LCmax(Y)検出時のLC(X)符号
をカメラから読み込む
S613
a = LCmax(X) − LCmin(X)
①
b = LCmax(Y) − LCmin(Y)
c = { +1 ・・・LCmax(X)検出時のLC(Y)符号が正の場合
−1 ・・・LCmax(X)検出時のLC(Y)符号が負の場合
S614
A

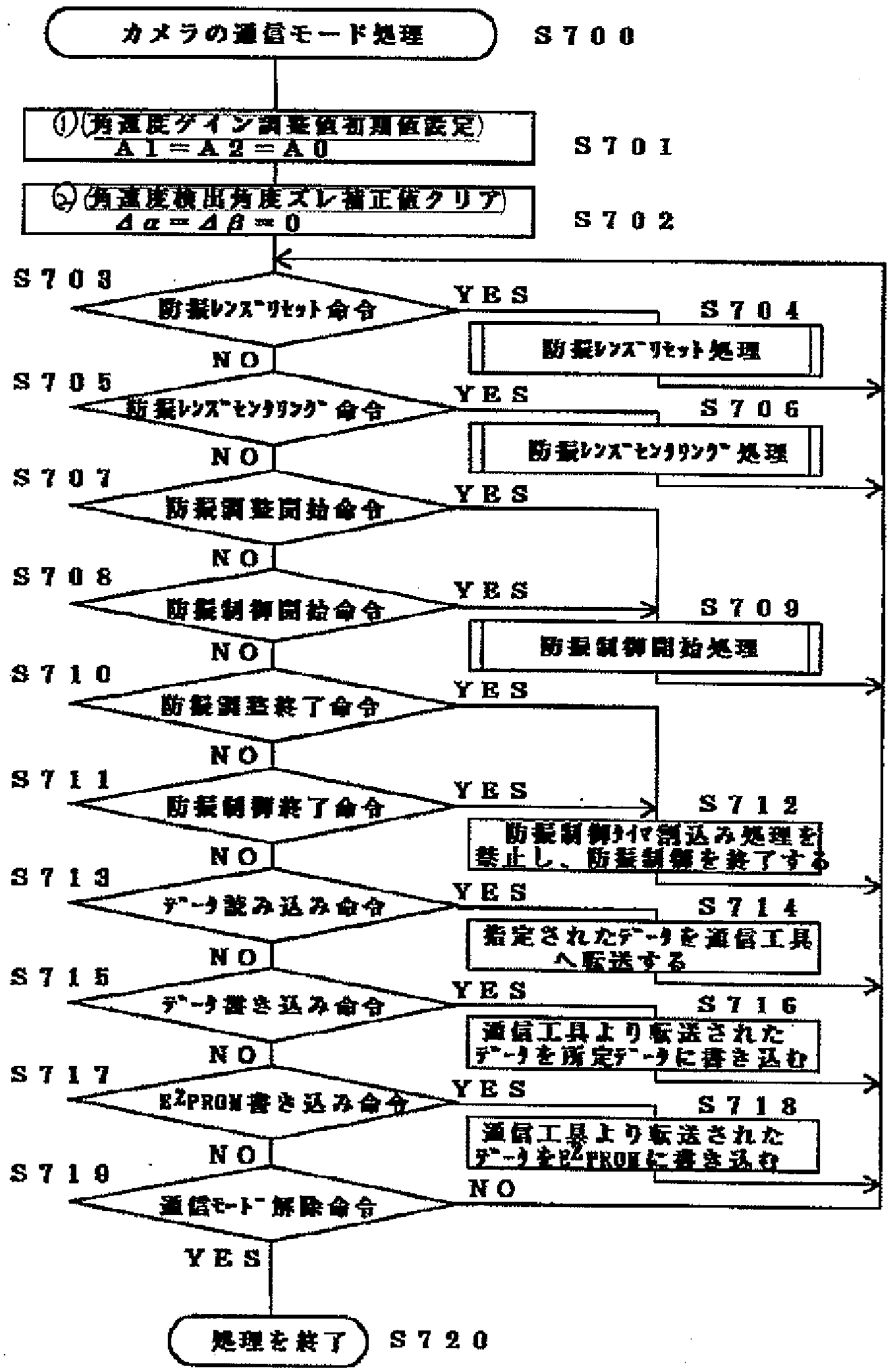
【図8】 FIG. 8


A
Y軸方向加振開始
S615
防振調整開始命令
S616
所定時間wait
S617
防振調整終了命令
S618
Y軸方向加振終了
S619
LCmax(X), LCmin(X), LCmax(X)検出時のLC(Y)符号
LCmax(Y), LCmin(Y), LCmax(Y)検出時のLC(X)符号
をカメラから読み込む
S620
d = LCmax(X) − LCmin(X)
e = LCmax(Y) − LCmin(Y)
1
f = ＋1 ‥‥ LCmax(Y)検出時のLC(X)符号が正の場合
−1 ‥‥ LCmax(Y)検出時のLC(X)符号が負の場合
S621
2
角速度検出回路ゲイン調節値算出
A1 = A0 × L01／a
A2 = A0 × L02／e
S622
3
角速度検出回路検出角度ズレ補正量算出
Δα = −f ×（L01／L02）×（d／a）
Δβ = −c ×（L02／L01）×（b／e）
S623
A1、A2、Δα、Δβをカメラの
E²PROMに書き込む
S624
A1／m、A2／m、Δα、Δβを
CPU1の所定データに書き込む
S625
X軸方向加振開始
S626
防振制御開始命令
S627
所定時間wait
S628
防振制御終了命令
S629
X軸方向加振終了
S630
B

【図9】 FIG.9

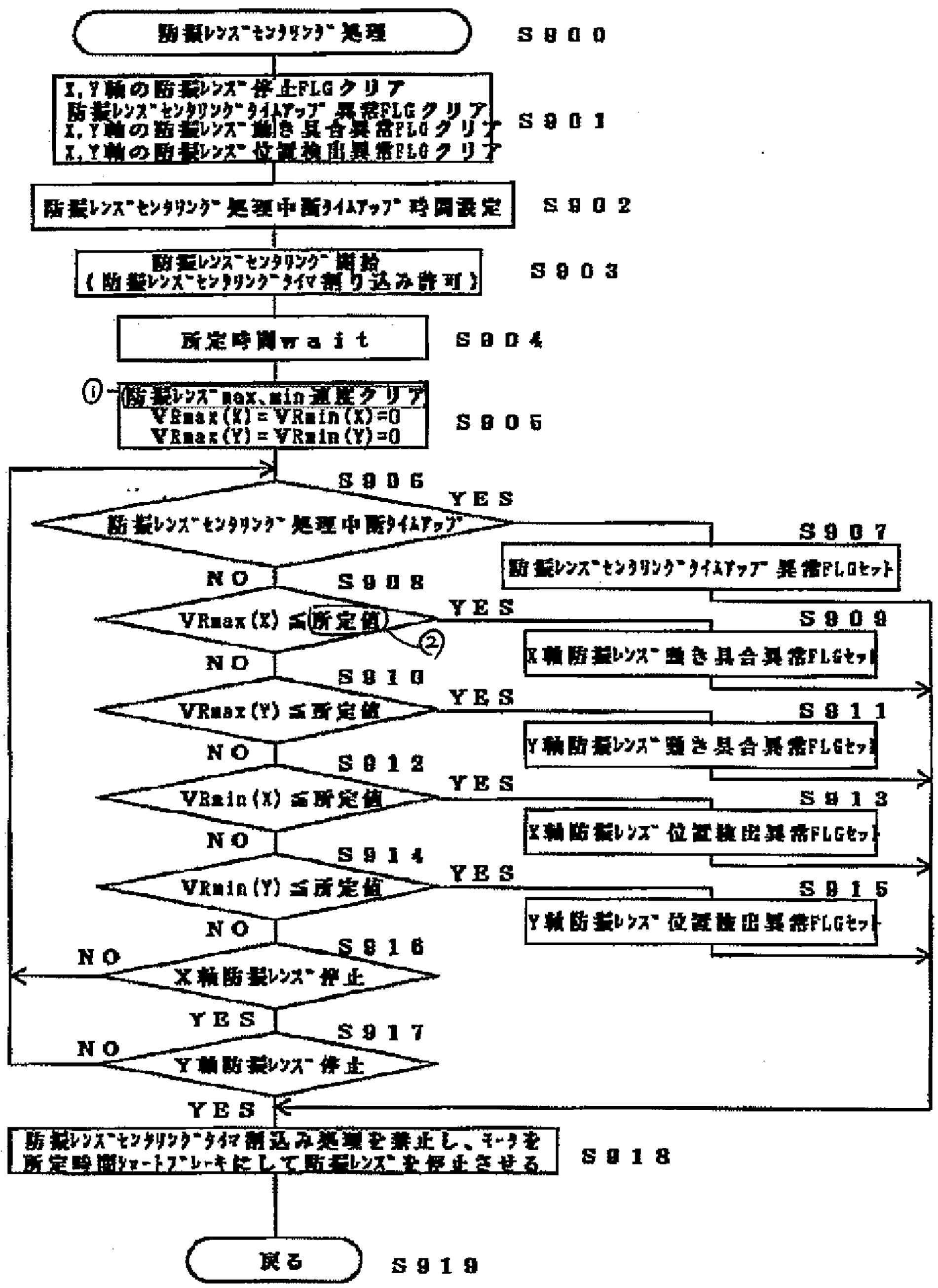

B
C
S631
LRmax(X), LRmin(X), ⊿Lmax(X), ⊿Lmin(X) をカメラから読み込む
g = LRmax(X) − LRmin(X)
S632
S633
|L01／m − g| ≦所定値
1
NO
YES
S634
|⊿Lmax(X)| ≦所定値
NO
YES
S635
|⊿Lmin(X)| ≦所定値
NO
YES
Y軸方向加振開始
S636
防振制御開始命令
S637
所定時間wait
S638
防振制御終了命令
S639
Y軸方向加振終了
S640
LRmax(Y), LRmin(Y), ⊿Lmax(Y), ⊿Lmin(Y) をカメラから読み込む
S641
h = LRmax(Y) − LRmin(Y)
S642
S643
|L02／m − h| ≦所定値
NO
YES
S644
|⊿Lmax(Y)| ≦所定値
NO
YES
S645
|⊿Lmin(Y)| ≦所定値
NO
S646
メカ不良、調整不良
YES
防振レンズリセット命令
S647
カメラを通信モードから解除
S648
処理を終了
S649

【図10】 FIG.10

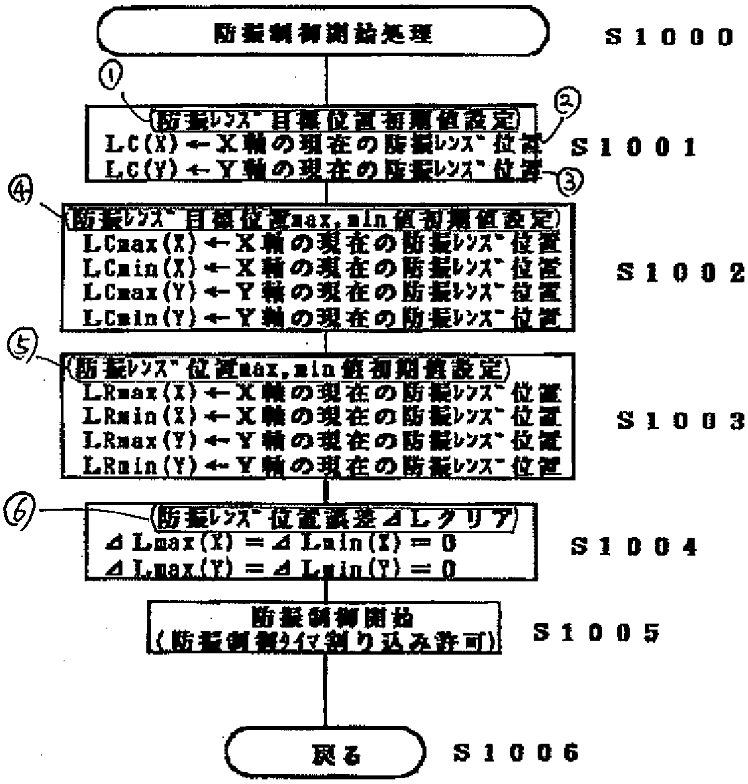


カメラの通信モード処理
S700
①(角速度ゲイン調整値初期値設定)
A1＝A2＝A0
S701
②(角速度検出角度ズレ補正値クリア)
Δα＝Δβ＝0
S702
S703
防振ﾚﾝｽﾞﾘｾｯﾄ命令
YES
S704
防振ﾚﾝｽﾞﾘｾｯﾄ処理
NO
S705
防振ﾚﾝｽﾞｾﾝﾀﾘﾝｸﾞ命令
YES
S706
防振ﾚﾝｽﾞｾﾝﾀﾘﾝｸﾞ処理
NO
S707
防振調整開始命令
YES
NO
S708
防振制御開始命令
YES
S709
防振制御開始処理
NO
S710
防振調整終了命令
YES
NO
S711
防振制御終了命令
YES
S712
防振制御ﾀｲﾏ割込み処理を禁止し、防振制御を終了する
NO
S713
ﾃﾞｰﾀ読み込み命令
YES
S714
指定されたﾃﾞｰﾀを通信工具へ転送する
NO
S715
ﾃﾞｰﾀ書き込み命令
YES
S716
通信工具より転送されたﾃﾞｰﾀを所定ﾃﾞｰﾀに書き込む
NO
S717
E²PROM書き込み命令
YES
S718
通信工具より転送されたﾃﾞｰﾀをE²PROMに書き込む
NO
S719
通信ﾓｰﾄﾞ解除命令
NO
YES
処理を終了
S720

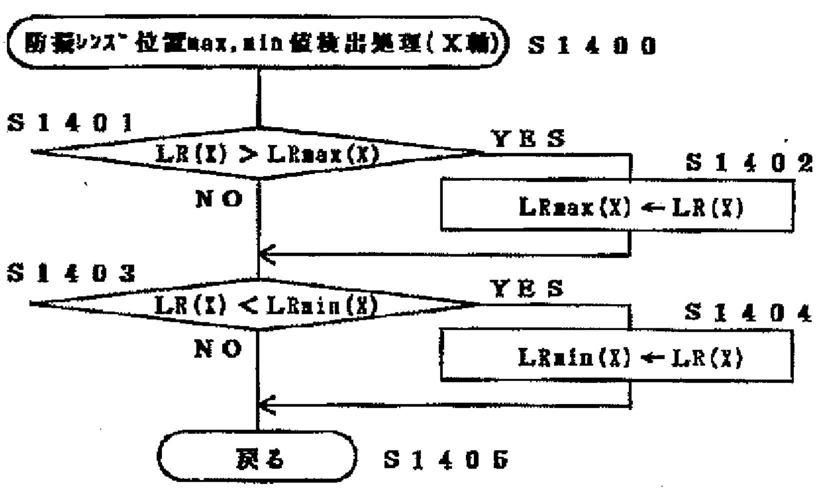
【図12】 FIG. 12


防振レンズ゛センタリング゛処理
S900
X,Y軸の防振レンズ゛停止FLGクリア
防振レンズ゛センタリング゛タイムアップ゛異常FLGクリア
X,Y軸の防振レンズ゛動き具合異常FLGクリア
X,Y軸の防振レンズ゛位置検出異常FLGクリア
S901
防振レンズ゛センタリング゛処理中断タイムアップ゛時間設定
S902
防振レンズ゛センタリング゛開始
(防振レンズ゛センタリング゛タイマ割り込み許可)
S903
所定時間wait
S904
①
防振レンズ゛max、min速度クリア
VRmax(X)=VRmin(X)=0
VRmax(Y)=VRmin(Y)=0
S905
S906
防振レンズ゛センタリング゛処理中断タイムアップ゛
YES
NO
S907
防振レンズ゛センタリング゛タイムアップ゛異常FLGセット
S908
VRmax(X)≦所定値
②
S909
X軸防振レンズ゛動き具合異常FLGセット
S910
VRmax(Y)≦所定値
S911
Y軸防振レンズ゛動き具合異常FLGセット
S912
VRmin(X)≦所定値
S913
X軸防振レンズ゛位置検出異常FLGセット
S914
VRmin(Y)≦所定値
S915
Y軸防振レンズ゛位置検出異常FLGセット
S916
X軸防振レンズ゛停止
S917
Y軸防振レンズ゛停止
防振レンズ゛センタリング゛タイマ割込み処理を禁止し、モータを所定時間ショートブレーキにして防振レンズ゛を停止させる
S918
戻る
S919

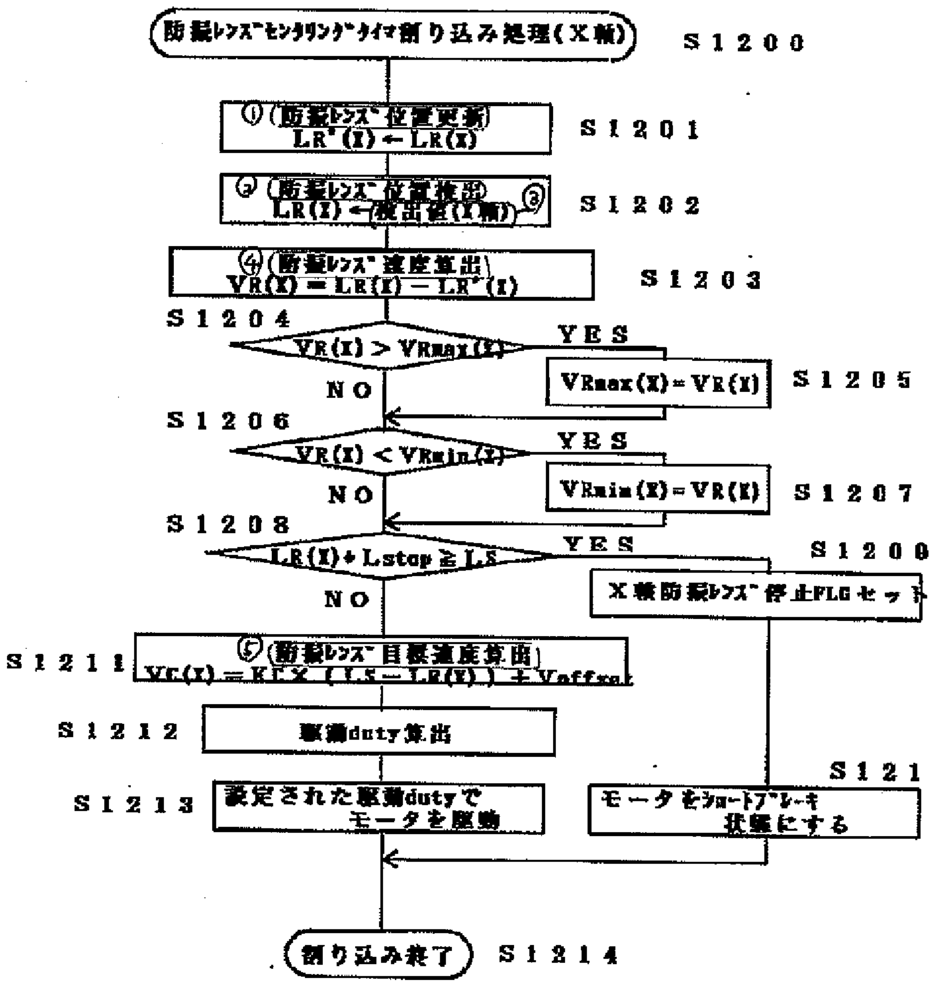
【図13】 FIG. 13



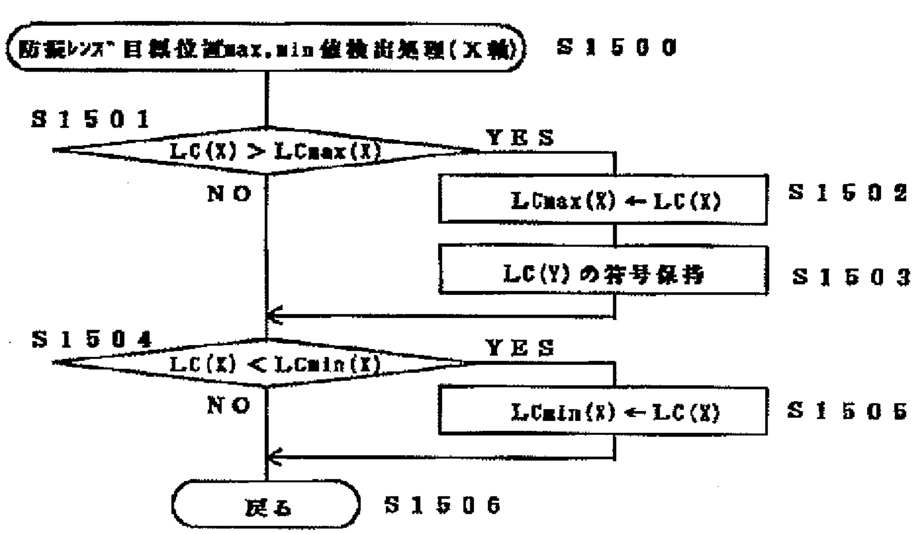
【図17】 FIG. 17



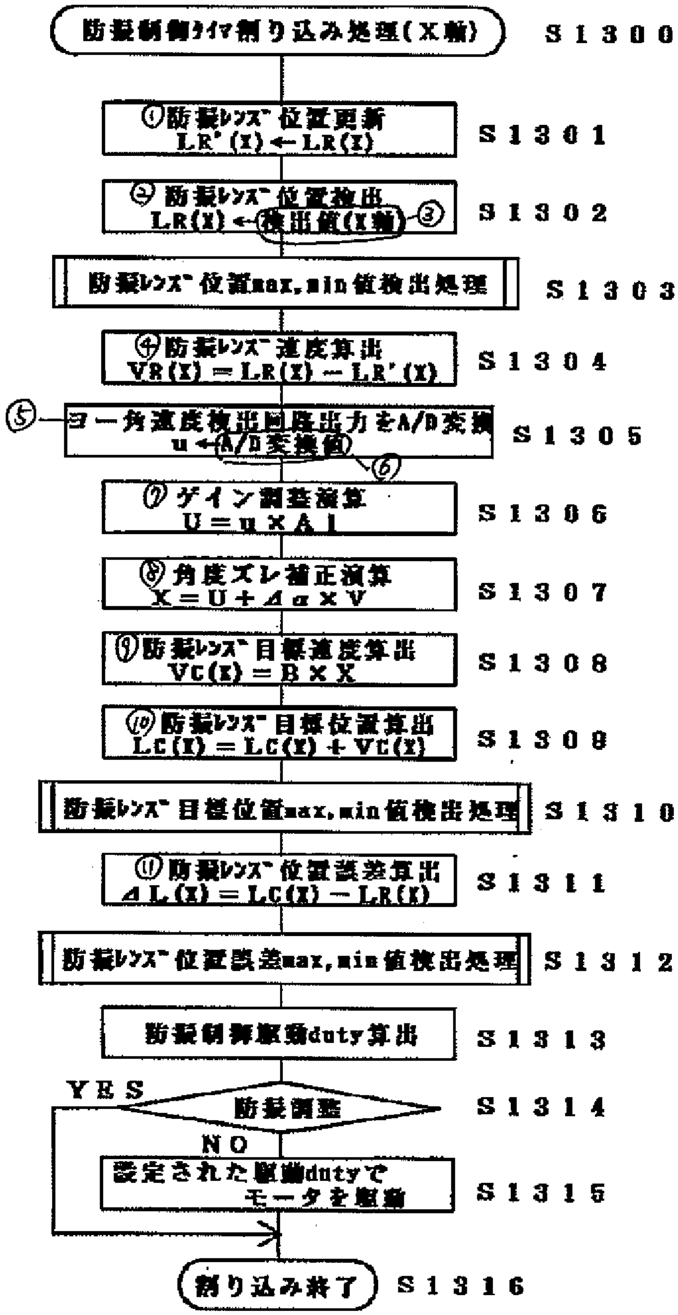
【図15】 FIG.15



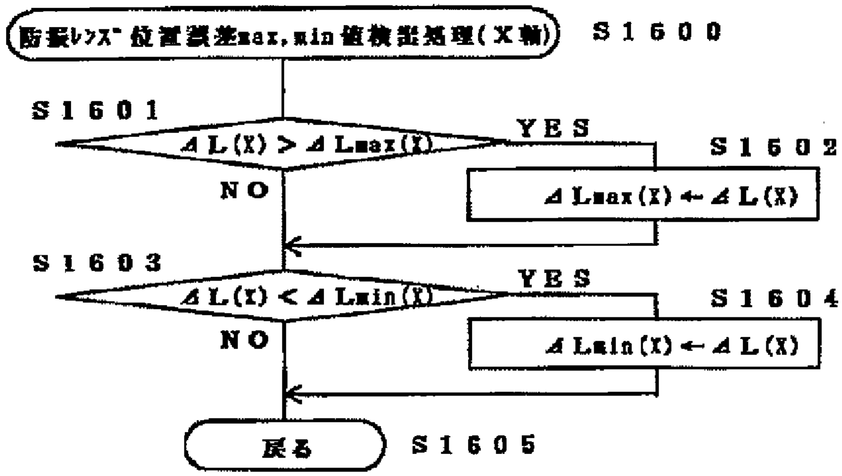
【図18】 FIG.18



【図16】 FIG. 16


防振制御ﾀｲﾏ割り込み処理（Ｘ軸）
S1300
①防振ﾚﾝｽﾞ位置更新
LR'(X)←LR(X)
S1301
②防振ﾚﾝｽﾞ位置検出
LR(X)←検出値(X軸)
③
S1302
防振ﾚﾝｽﾞ位置max,min値検出処理
S1303
④防振ﾚﾝｽﾞ速度算出
VR(X)＝LR(X)－LR'(X)
S1304
⑤
ヨー角速度検出回路出力をA/D変換
u←A/D変換値
⑥
S1305
⑦ゲイン調整演算
U＝u×A1
S1306
⑧角度ズレ補正演算
X＝U＋Δα×V
S1307
⑨防振ﾚﾝｽﾞ目標速度算出
VC(X)＝B×X
S1308
⑩防振ﾚﾝｽﾞ目標位置算出
LC(X)＝LC(X)＋VC(X)
S1308
防振ﾚﾝｽﾞ目標位置max,min値検出処理
S1310
⑪防振ﾚﾝｽﾞ位置誤差算出
ΔL(X)＝LC(X)－LR(X)
S1311
防振ﾚﾝｽﾞ位置誤差max,min値検出処理
S1312
防振制御駆動duty算出
S1313
YES
防振調整
S1314
NO
設定された駆動dutyで
モータを駆動
S1315
割り込み終了
S1316

【図19】 FIG. 19



【図20】 FIG. 20